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ABSTRACT

This packet consists of the instructor and trainee manuals for a concrete practices and procedures course. The instructor manual contains a schedule for an 80-hour, 10-day course and instructor outline. The outline provides a step-by-step description of the instructor's activities and includes answer sheets to accompany questions on information presented in films, examples, homework assignments, answer sheets to exercises, and directions for hands-on activities. The trainee manual is divided into 11 sections. Each section may contain some or all of these components: a list of objectives, instructional or informational materials, exercises, and worksheets. The 11 sections cover the following: safety, construction math, project planning, site preparation, forming for placement, placement and consolidation, finishing and curing, form stripping and clean-up, concrete admixtures, sawing concrete, and concrete repair and rehabilitation. Appendixes contain the following: glossary of general cement and concrete terms, glossary of terms for concrete tools and equipment, and glossary of terms for concrete formwork and accessories. (YLB)

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ED 379 418

LABORERS-AGC
EDUCATION AND TRAINING FUND

Concrete

Practices & Procedures

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

Instructor Manual

TRAINEE

MANUAL

Laborers-AGC Education and Training Fund
37 Deerfield Road
Pomfret Center, CT 06259

CE066098

80-HOUR CONCRETE COURSE SCHEDULE

Day 1: **8:00 - 1:30 Classroom**
Introduction and paperwork
- Section I - Safety
  Videos and review:
    "An Awareness in Hazard Recognition"
    "Working At Heights Safely"
  Hazard Communication program

1:30 - 4:30 Classroom
- Section II - Construction Math
  Video and review:
    "Basic Principles of Transfer of Grade"
  Measuring tools and techniques

Day 2: **8:00 - 9:00 Classroom**
Measuring tools and techniques (continued)

9:00 - 4:30 Hands-On
Horizontal measuring
Use of builder's level and laser level
Vertical measuring and transfer of grade

Day 3: **8:00 - 10:30 Classroom**
- Section III - Project Planning
  Site inspection
  Scale drawing of projects
  Measuring and notes
  Construction Plan

- Section IV - Site Preparation
  Video and review:
    "Soils and Compaction"

10:30 - 3:00 Hands-On
- Section IV - Site Preparation
  Site layout
  Line and grade for projects
  Squaring of structures and batterboards

3:00 - 4:30 Hands-On
- Section V - Forming for Placement
  Construct forms for projects

Day 4: **8:00 - 12:00 Hands-On**
- Section V (continued)
  Continue form construction

Day 4: **12:30 - 2:30 Classroom**

- Section VI-Placement and Consolidation
  - Videos and Questions:
    - "Transporting and Placing Quality Concrete"
    - "Concrete Vibration"

2:30 - 4:30 Classroom

- Section VII - Finishing and Curing
  - Video and questions:
    - "Finishing and Curing Quality Concrete"

Day 5: **8:00 - 12:00 Hands-On**

Place concrete
- Curb and gutter
- Slab or sidewalk
- Footing

Finishing and clean-up

12:30 - 1:30 Classroom

- Section VIII - Form Stripping and Clean-Up
  - Video and review:
    - "The Winning Ticket"

1:30 - 4:30 Classroom

- Section IX - Concrete admixtures
  - Air entrainment
  - Plasticizers
  - Accelerators
  - Retarders
  - Pozzolans

Day 6: **8:00 - 9:00 Hands-On**

Strip and clean forms from first placement

9:00 - 4:30 Hands-On

Practice wall form set-ups and leave forms ready for placement
- Form columns - 2nd placement
- Form slab - 2nd placement
- Practice with number and instruments

Day 7: **8:00 - 12:00 Hands-On**

Place concrete using pump
- Wall and columns
- Slab or sidewalk

Finishing and clean-up

12:30 - 1:30 Classroom

- Section X - Sawing Concrete

Video and review:
- "Concrete Saws"

1:30 - 4:30 Classroom

- Section XI - Concrete Repair & Rehabilitation
  - Methods
  - Tools and equipment
  - Materials

Day 8: 8:00 - 10:00 Hands-On

Concrete Sawing Demonstration
- Set-up
- Maintenance checks
- Sawing

Concrete Repair Demonstration
- Set-up
- Surface preparation
- Review of repair methods

10:00 - 4:30 Hands-On

Concrete Sawing
Surface Preparation

Day 9: 8:00 - 11:00 Hands-On

Strip Forms from Concrete Placement
Clean and oil
Storage

11:00 - 4:30 Hands-On

Sawing and Surface Preparation (continued)
Begin Concrete Repair
- Overlay
- Horizontal and vertical cracks
- Damaged concrete repair

Day 10: 8:00 - 12:00 Hands-On

Concrete Repair (continued)
Finish and cure

12:30 - 2:30 Hands-On

Site Clean-up

2:30 - 4:30 Classroom

Review and Evaluation

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Introduction

Instructor Outline, Day One, 8:00 - 8:30

1. Introduce yourself and tell of your background with the Laborers and the training program.

2. Have each trainee introduce himself/herself and tell of their work experience as a laborer - how long a member and what type of work performed.

3. Read through site rules and regulations and explain Training Center protocol.

4. Have class fill out paperwork necessary for expenses, etc..

5. Express importance of communication between foreman and workers. Stress safety as the best reward for good communication. These discussions will help relax the class and help identify their job attitudes.

Section I: Safety

Instructor Outline, Day One, 8:15-10:00

1. Begin safety discussion by stressing the importance of being safety minded at all times, on and off the job.

2. Stress that laborers must develop a safety awareness and build this awareness into everything they do at the construction site.

3. Construction crews must be familiar with state and federal safety and health regulations and learn to take many safety precautions on the job.

4. Talk about employees' rights under OSHA and also their obligations to the employer.

5. Show Film - "An Awareness in Hazard Recognition".

6. Discuss and highlight, Subpart Q - Concrete Masonry Construction Safety Standards 1926.700 - 1926.706 (pages 2-6 in trainee manual).

7. Develop components for a safety awareness program, ask trainees for input and establish the following:

    a. Personal Protective Equipment (P.P.E.), make list.
    b. Visual Aids such as posters for constant reminders.
    c. Tool box meeting with foreman-10 to 15 minutes, once a week.
    d. Safety training for new employees.
    e. Safety meeting with supervisor once a month, or whenever a new job starts.
    f. Report, repair, or tag faulty equipment.
    g. Previous experience with accidents.
    h. Good housekeeping procedures.

i. First Aid training and procedures.
j. Fire and emergency procedures.
k. Material Safety Data Sheets (MSDS) for hazardous material identification and precautions.
l. Job attitude - learn to be safety conscious.

8. Show Film - "Working at Heights Safely" and review question sheet (page 7 in trainee manual).

9. Issue hard hats, eye protection and ear protection.

10. Assign pages 8-20 for research at home.

11. Present Hazard Communication Program.

Instructor's answer sheet for "Working at Heights Safely".

1. What are the five areas of priority dangers presented in the film?

   a. Scaffolding ***b. Swinging scaffolds***
   c. Ladders ***d. Wall openings or edges of structures***
   e. Floor openings on structures

2. How much weight should a scaffold be able to support?

   Four times its maximum rated load.

3. At what distances should a scaffold be secured to a structure? (Vertically and horizontally.)

   Every 30' horizontally and every 26' vertically.

4. How much weight should the cable on a swinging scaffold support?

   6 times the weight of the scaffold.

5. How should the testing of swinging scaffold be done?

   By putting 4 times the maximum load with the scaffold 1 foot off the ground.

6. What is the proper angle ratio for placement of ladders? And how far above the landing should a ladder extend?

   a. A ratio of 1':4' ***b. 3'***

7. Should loads be carried on ladders? ***No.***

8. What do guard rails consist of?

   4" toe board, mid-rail, and a top-rail at a minimum of 42".

9. If guard rail is temporarily removed, what should be done?
   It should be replaced immediately.

10. How should floor openings be protected?

    With standard guard rails or covered with a floor cover of standard strength construction and secured against accidental displacement.

11. Distance between a hoist and building should be ***ramped*** or ***platformed***.

12. What personal protective equipment was used in the film pertaining to working at heights safely?

    Safety belts, lanyards and lifelines

13. When should extraordinary safety precautions be used when working at heights?

    a. Scaffolding ***b. Swinging scaffolds***
    c. Ladders ***d. Wall openings or edges of structures***
    e. Floor openings on structures

Section II: Construction Math And Measurements

Instructor Outline, Day One, 1:30 - 4:30
Day Two, 8:00 - 4:30

Measuring Systems

1. Describe the measuring systems used in the United States and Canada.

2. Describe the difference between the U.S. Customary and the Decimal foot.

3. Describe the use of fractions and hundredths for units smaller than 1" or 0.10'.

4. Have the class work the exercises on pages 22 and 23 (in the student manual) on basic arithmetic with the decimal system. Be sure to teach rounding procedures.

5. Discuss how the decimal system is used almost exclusively for construction measurements due to the ease of working arithmetic functions with decimals, instead of fractions.

6. Describe the techniques used to convert from U.S. Customary expressions to Decimal feet using the 1/8"=.01' method by:

   a. Refer to page 24 in the student manual: The Inch to Decimal Comparison Table.
   b. Have the students compare quarter foot intervals in both systems as follows:
   c. Refer to page 25 in the student manual: The Inch to Decimal Conversion Table. Note to students that the table starts with the basic ratio of 1/8" = .01'. Have the students study the table and familiarize themselves with the basic conversion parts, especially the fractions up to 1 inch, and the whole inch to decimal conversions.
   d. Have the class work the exercise on page 26 using the conversion table .

7. Demonstrate the conversion process from U.S. Customary system to Decimal feet without the table using the examples on page 27.

8. Have the class work exercise #4 on page 27 without using a table to Convert Inches and Fractions to Feet, Tenths and Hundredths.

9. Demonstrate the conversion process from Decimal feet to U.S. Customary system without the table using the examples on page 28.

10. Have the class work exercise 5 on page 28 without using a table to Convert Feet, Tenths and Hundredths to Inches and Fractions..

11. Hand out engineer's folding rulers to the class. Refer to page 29 in the student manual and discuss the carpenter's side and the engineer's side of the ruler.

12. After any questions on reading the folding rule, refer to page 30 in the student manual. Explain to the class that page 30 is a measuring worksheet using the carpenter's side and the engineer's side of the folding rule. Have the class give individual answers to see if they are learning to read the rule correctly.

Horizontal and Vertical Measurements

13. Discuss that with only a few exceptions, all construction measurements will be done either horizontally or vertically.

14. Demonstrate how to make length measurements using a tape measure, a rag tape or a 6' folding rule.

15. Specify that whenever making a length measurement, care must be taken to insure that the tape is without sag (tight), held level (horizontal) and in line with the points to be measured.

16. Specify that if the tape cannot be held on the points to be measured, due to obstructions or sloped ground, the tape must still be held level and the distance transferred from the tape to the ground vertically using a plumb bob.

17. Display a grade rod and describe the correct procedure to hold and read the rod.

18. Describe the basics of differential leveling and grade transfer using Above Sea Level (ASL) elevations.

19. Set up horizontal measuring practices using rag tapes, 6 foot folding rules and plumb bobs. Perform measurements up and down slopes, over obstacles, and on flat ground.

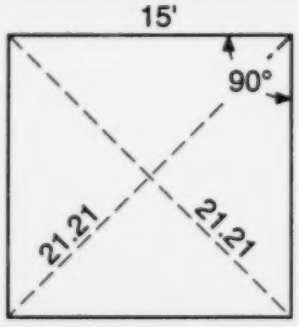
20. Demonstrate how to set-up a builder's level, an auto level and a laser level. Have the trainees practice with each instrument. Practice should include set-up and leveling, focusing and reading a grade rod.

21. Using a bench mark elevation, practice grade transfer and differential leveling. Show the trainees how to record readings and do calculations using rod readings and elevations.

Squaring Principles

22. Discuss that in order for an object to be square or rectangular they must have equal diagonals.

23. Have the class follow the squaring example A on page 31 while you demonstrate the procedure to calculate the diagonals of a square using the formula and Figure 2-1 below.



Formula: Diagonal = side length x 1.414

Example: Square is 15'x15'

diagonal = 15'x1.414
diagonal = 21.21'

Figure 2-1

21. Have the class work exercise A on page 31.

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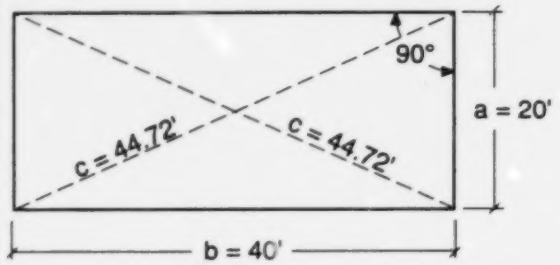
22. Have the class follow the squaring example B on page 31 while you demonstrate the procedure to calculate the diagonals of a rectangle using the formula and Figure 2-2 below.



Formula: $a^2 + b^2 = c^2$
Where: a = width of the rectangle
b = length of the rectangle
c = length of the diagonal

Example: Rectangle is 20'x40'
diagonal = √(20'x20') + (40'x40')
diagonal = √(400+1600)
diagonal = √2000
diagonal = 44.72'

Figure 2-2

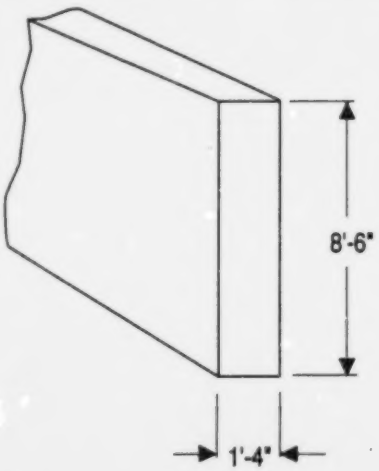
23. Have the class work exercise B on page 31. Explain how to use the calculator to find the square roots for the rectangular diagonals.

Method for Estimating Concrete Quantities - Regular Shapes

24. Describe that an initial step taken by every concrete user is the preparation of a clear and accurate concrete estimate. The main purpose of the estimate is an accurate description of required concrete quantities, whether the job is small or large, or the estimate is brief of detailed. This estimate enables the builder to predict his material requirements and is useful in determining the time it will take to place the concrete and in scheduling equipment for placement.

25. Demonstrate that the first step of an estimate is to isolate all concrete portions with an identical cross section, or all portions with the same width and thickness. Next, lengths of all concrete portions with the same cross section are totalled. The total length is multiplied by the cross sectional area to arrive at the volume. All dimensions used must be in feet, therefore volume will be expressed in cubic feet.

Have the class refer to page 32 in student manual and illustrate as shown in Figure 2-3.



A structure is to be built which has a plain footing wall with a uniform width of 1 ft. 4 in., and a depth of 8 ft. 6 in.. The lengths of the footings are: 10 ft., 16 ft., 18 ft., and 12 ft.. To determine the volume of the footing wall:

a. Add all the lengths: 10'+16'+18'+12'= 56 ft.

b. Convert the cross section dimensions from feet and inches to feet and decimals: 1'-4"=1.33' and 8'-6"= 8.5'

c. Calculate the volume: 56'x1.33'x8.5' = 633.08 cu. ft.

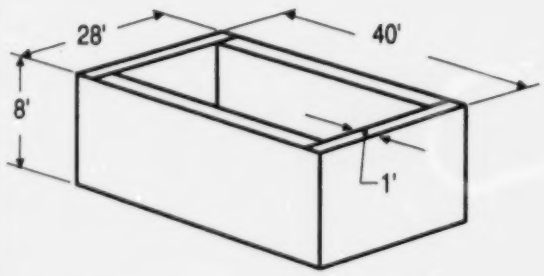
Figure 2-3

26. Discuss that concrete is always ordered in cubic yard quantities. One cubic yard is equal to 27 cubic feet. After calculating the volume of a project in cubic feet, divide the number of cubic feet by 27 to find cubic yards. In Figure 2-3 the cubic yardage in the footing wall is:
(633.08 ÷ 27 = 23.44 cubic yards)

27. Items such as block-outs for door and window openings must be carefully checked to be sure that the volume occupied by these openings is not shown on the estimate as being occupied by concrete. These volumes are known as negative quantities and must be subtracted from the total concrete estimate.

28. In calculating the volume of concrete in a structure with corners, care must be taken by the estimator to insure that the corner volume is not counted twice. One method of preventing this error is to show the corner deduction in one portion of the calculation. Have the class refer to page 32 and work the following example with the class.

Example: Calculate the volume of concrete needed for a rectangular walled structure 8 feet high and 1 foot thick, with sides 28 feet wide and 40 feet long.



2 sides @ 28' = 56'
2 sides @ 40' - 4' = 76'

Find the volume by using the following process:

(56'+76') x 1' x 8' = 1056 cubic feet
1056 cubic feet ÷ 27 = 39.11 cubic yards

Figure 2-4

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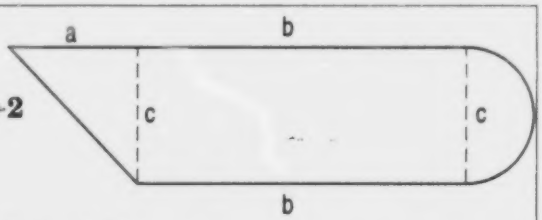
Method for Estimating Concrete Quantities - Irregular Shapes

29. Describe that when an area has irregular shapes it is easiest to divide the area into a group of regular shapes. Have the class refer to page 33 and work the following example with the class.

Example: Calculate the volume for the irregular shaped slab in Figure 2-5 if slab is 6" thick and length a=10', b=15' and c=8'.

Triangular area ac = 10' x 8' + 2 = 40.00 sq. ft
Rectangular area bc = 15'x8' = 120.00 sq. ft
Semicircular area c = 3.1416x(4x4)÷2
= 25.13 sq. ft.

(area of a circle = πR^2)



Calculate the area using the formulas shown above then total:

Triangular area ac	=	**40.00**	**sq. ft.**
Rectangular area bc	=	**120.00**	**sq. ft.**
Semicircular area c	=	**+25.13**	**sq. ft.**
Total	=	**185.13**	**sq. ft.**

Multiply the total area by the depth (0.5 feet) to express the area as cubic feet:

185.13 x .5 = 92.57 cu. ft.

Divide the total cubic feet by 27 to express the volume as cubic yards:

92.57 cu. ft. ÷ by 27 = 3.43 cu. yd.

Figure 2-5

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30. The basis for estimating concrete quantities is the same in simple or complex structures. In complicated structures and in areas of non-uniform thickness or shape the structure is divided into small, uniform shapes which are calculated and then totalled to produce an accurate concrete quantity estimate. The key to an accurate concrete estimate is to be certain that each volume is correctly calculated before moving on to the next item.

31. Another example of a common irregular shape is a standard curb and gutter. Have the class refer to page 33 and work the following example with the class. Make the curb and gutter section into a regular shape by adding the height of the curb onto the length as shown in Figures 2-6 and 2-7.

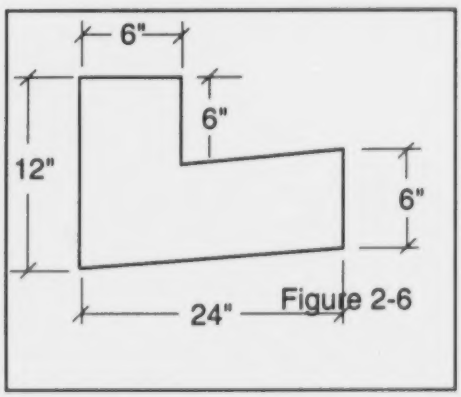

Figure 2-6

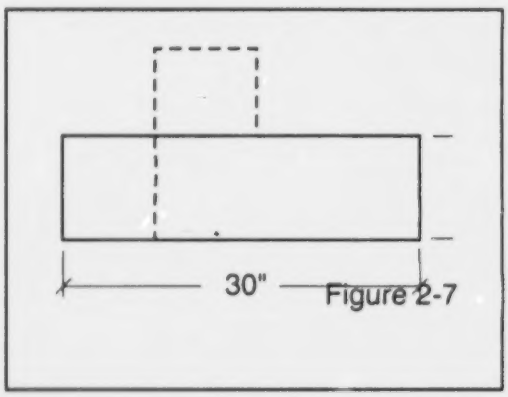

Figure 2-7

To calculate the concrete quantity for the standard curb and gutter section shown:

6" x 30" x Length ÷ 27 = Cubic Yards

32. Have the class refer to page 34 for basic concrete estimating formula and review the use of each formula.

33. Assign the quantity calculations on page 35 as homework.

Instructor's Answer Sheet for Exercise #1

Round all answers to the second decimal place.

Add the following figures. Be sure that the decimal point is in the correct place.

1. 5.06 + 10.75 + 16.03 = ***31.84***
2. 10.95 + 0.06 + 9.17 = ***20.18***
3. 3.951 + 18.976 + 21.977 = ***44.90***
4. 0.678 + 1.766 + 28.115 + 9.002 = ***39.56***
5. 16.773 + 8.76 + 30.4 + 19.111 + 0.022 = ***75.07***

Subtract the following:

1. 5.02 - 0.01 = ***5.01***
2. 10.28 - 5.67 = ***4.61***
3. 106.29 - 0.66 = ***105.63***
4. 130.5 - 1.55 = ***128.95***
5. 0.695 - 0.34 = ***0.36***

Multiply the following:

1. 5.0 x 0.6 = ***3.0***
2. .06 x .05 = ***0.003***
3. 1.3 x 2.51 = ***3.26***
4. 21.31 x 2.01 = ***42.83***
5. 32.105 x 3.006 = ***96.51***

Divide the following and place the decimal point in the proper place:

1. 500 ÷ 50. = ***10.00***
2. 50.9 ÷ 15. = ***3.39***
3. 56.7 ÷ 2.5 = ***22.68***
4. 622.5 ÷ 2.66 = ***234.02***
5. 1005.99 ÷ .067 = ***15,014.78***

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Instructor's Answer Sheet for Exercise #2

Round all answers to the second decimal place.

	Multiplication			Division	
1.	5x7 =	= ***35.00***	1.	15÷5	= ***3.00***
2.	3x10 =	= ***30.00***	2.	200÷10	= ***20.00***
3.	10x10	= *100.00*	3.	1134÷54	= ***21.00***
4.	14x13	= ***182.00***	4.	570÷114	= ***5.00***
5.	101x51	= ***5,151.00***	5.	5826÷6	= ***971.00***
6.	1034x201	= ***207,834.00***	6.	932880÷845	= ***1,104.00***
7.	.51x 21	= ***10.71***	7.	.25÷.5	= ***0.50***
8.	1.21x.09	= ***0.11***	8.	4.5÷1.5	= ***3.00***
9.	6.18x1.16	= ***7.17***	9.	100÷.25	= ***400.00***
10.	600x1.01	= ***606.00***	10.	341.4÷2.7	= ***126.44***
11.	195.5x10	= ***1,955***	11.	.369÷.80	= ***0.46***
12.	64.555x.50	= ***32.28***	12.	5494.4÷54.4	= ***101.00***

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Instructor's Answer Sheet for Exercise # 3

Use the converion table on page 25 to convert the following U.S. Standard expressions to decimal expressions:

1. 1/8" = ***0.01'***
2. 1" = ***0.08'***
3. 5" = ***0.42'***
4. 11" = ***0.92'***
5. 7/8" = ***0.07'***
6. 8" = ***0.67'***
7. 1/2" = ***0.04'***
8. 3" = ***0.25'***
9. 3/8" = ***0.03'***
10. 9" = ***0.75'***
11. 6" = ***0.50'***
12. 3/4" = ***0.06'***
13. 12" = ***1.00'***
14. 2" = ***0.17'***
15. 1/4" = ***0.02'***
16. 7" = ***0.58'***
17. 10" = ***0.83'***
18. 5/8" = ***0.05'***
19. 4" = ***0.33'***
20. 7/8" = ***0.07'***

Instructor's Answer Sheet for Exercise # 4

a. $2\ 1/2" = 0.21'$ b. $5\ 7/8" = 0.49'$ c. $7\ 3/8" = 0.61'$

d. $8\ 3/4" = 0.73'$ e. $3\ 1/2" = 0.29'$ f. $33\ 3/4" = 2.81'$

f. $27\ 1/4" = 2.27'$ g. $75\ 1/2" = 6.29'$ h. $4\ 1/4" = 0.35'$

i. $3\ 5/8" = 0.30'$ j. $6\ 3/4" = 0.56'$ k. $9\ 1/2" = 0.79'$

l. $8\ 3/4" = 0.73'$ m. $7\ 1/4" = 0.60'$ n. $21\ 1/2" = 1.79'$

o. $75\ 1/2" = 6.29'$ p. $2\ 7/8" = 0.24'$ q. $5\ 1/8" = 0.43'$

r. $6\ 1/4" = 0.52'$ s. $9\ 3/8" = 0.78'$ t. $1\ 1/4" = 0.10$

u. $37\ 1/8" = 3.09'$ v. $10\ 3/4" = 0.89'$ w. $77\ 1/2 = 6.46'$

Instructor's Answer Sheet for Exercise # 5

a. 1.59 = *1'-7 1/8"*

b. 6.87 = *6'-10 1/2"*

c. 9.36 = *9'-4 3/8"*

d. .95 = *11 3/8"*

e. .22 = *2 5/8"*

f. 3.45 = *3'-5 3/8"*

g. 1.63 = *1'-7 3/4"*

h. 10.73 = *10'-8 3/4"*

i. 1.14 = *1'-1 3/4"*

j. 12.06 = *12'-3/4"*

k. 11.91 = *11'-10 7/8"*

l. 4.41 = *4'-4 7/8"*

m. 9.69 = *9'-8 1/4"*

n. 1.24 = *1'-2 7/8"*

o. 1.71 = *1'-8 1/2"*

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Instructor's Answer Sheet for Exercise #6

Instructor note: The following answers are interpreted and small differences are to be expected from the class.

STANDARD RULE			ENGINEER'S RULE		
A-B	*5 1/8"*	F-G *2 7/16"*	A-B	*.43'*	I-J *.14'*
B-C	*3 5/8"*	G-H *3 5/8"*	B-C	*.30'*	G-H *.30'*
C-D	*4 1/8"*	H-I *4 7/16"*	C-D	*.34'*	H-I *.37'*
D-E	*6 3/16"*	I-J *1 11/16"*	D-E	*.52'*	I-J *.14'*
E-F	*4 7/8"*	J-K *2 3/8"*	E-F	*.40'*	J-K *.20'*

Instructor's Answer Sheet for Exercise # 7

Calculate the quantity of concrete required to pour the following structures. Express your answers in Cubic Yards.

Sidewalk:

1. 4" x 4' x 240' = ***11.73 cu. yds.***
2. 5" x 5' x 820 = ***63.78 cu. yds.***

Slabs:

3. 5" x 24' x 48' = ***17.92 cu. yds.***
4. 6" x 36' x 54' = ***36.00 cu. yds.***

Walls:

5. 8" x 8' x 140' = ***27.79 cu. yds.***
6. 12" x 10' x 190' = ***70.37 cu. yds.***

Footings:

7. 10" x 16" x 140' = ***5.72 cu. yds.***
8. 12" x 2' x 280' = ***20.74 cu. yds.***

Round columns:

9. 3' diameter x 24' high = ***6.28 cu. yds.***
10. 5' diameter x 32' high = ***23.27 cu. yds.***

Curb and Gutter:

11. 240' long = ***11.11 cu. yds.***
12. 650' long = ***30.09 cu. yds.***

Section III: Project Planning

Instructor Outline, Day Three, 8:00 - 10:30

1. Discuss that planning a construction project begins by inspecting the project site, taking notes, and making sketches. Using information from the site inspection the contractor can start to formulate a plan for site preparation, forming systems, materials and equipment storage, concrete placing schedules, and the size of the construction crew.

2. These plans are necessary to complete a project successfully. By using quality construction practices, skilled workers, and a very detailed construction plan, a project can be completed on schedule and according to specifications.

3. Explain to trainees the type of projects to be constructed during the course. Refer trainees to page 38 in the student manual. Review the scale drawing of the hands-on training area (project area) which includes the class projects.

4. Inspect the construction area and have the class take notes and measurements and make rough sketches of the site to include the course projects.

5. During the site inspection and drawing review, instruct the trainees to begin formulating a construction plan for their class projects. Refer trainees to page 39 in the student manual and discuss the construction plan outline.

6. The construction plan should include the following items:

Excavation	Spoil storage, access to the excavation by workers and material handling equipment, etc.
Rough grading	Leveling after excavation, locating reference points and grade control methods.
Compaction	Size and type of compaction equipment for this project, safety of workers in excavation during compaction.
Forming	Types of forming systems to be used, line and grade control of forms, bracing and shoring methods.
Placing	Access to forms, equipment necessary and size of crew.
Form stripping	Cleaning of forms, application of form release oil and storage of forms and materials.

7. During discussion of the project plan, instruct the trainees to include the dimension of the class projects on their shop drawings on page 38. This dimensioning process will help the trainees during site preparation and forming for placement.

8. During the planning stage be sure to remind the trainees to build safety practices into their projects, as this will help maintain a constant safety awareness at the job site.

9. Project planning must be carried out carefully so as not to leave out any details that may cause accidents, form failure, or other project delays.

10. Assign pages 40-52 in student manual as homework.

Section IV: Site Preparation

Instructor Outline, Day Three, 8:00 - 10:30

1. Review homework or questions from Day 1.

2. Lecture compacting soil with correct moisture for sidewalks, curbs, footings, and slabs.

   a. To begin site preparation the first step is to prepare the subgrade by removing all foreign materials such as sod, roots, muck, etc.

   b. If preparing for a slab on grade, such as a sidewalk or a floating slab, the subgrade material should be leveled to rough grade. Reference points can now be used to determine whether fill is needed or material has to be removed to get the proper subgrade level.

   c. When fill is added to the subgrade, care must be taken to compact the fill thoroughly to prevent settling which will cause cracking after the slab is poured. Fill should be added in 4" to 6" layers depending on size and type of compaction equipment.

   d. Compaction can be accomplished by using hand tampers, rollers, vibratory compactors, rammers, or air-powered tampers. The type of equipment used will depend on the size and type of the project and the type of soil to be compacted.

   e. Show film and review Laborers-AGC TIPS #8 on Soils and Compaction. Refer to pages 54-56 in the student manual.

3. Site layout begins by constructing batter boards to determine precisely where the outside edge of the foundation will be located. Have the class refer to page 64 Figure 4-12.

   a. To determine the location of the batter boards, roughly position a stake at each corner of the structure. The batter boards should be set back far enough so they will not interfere with excavation or construction.

   b. Batter boards should be constructed with 2x4 stakes and a 2x4 cross piece leveled with a 2' or 4' level. Batter boards can be leveled from corner to corner using a line level, a hand level or a builder's level.

c. Project can be squared up as practiced earlier and the excavation can be marked with lime or spray paint and the stringlines removed for digging.

4. Where excavations are required always be sure to call "Diggers Hotline" to have all underground utilities located and marked before any digging is done.

5. Be sure to stockpile the excavated material close enough for easy backfilling, but do not restrict truck access during construction or overburden the excavation walls that could cause cave-ins.

6. Keep close control of the depth of the excavation to prevent over-excavation and creating an unevenly compacted subgrade which could settle and cause cracking in the foundation wall.

7. Always remember to make the excavation safe before sending a crew into it.

8. Assign pages 57-66 as homework.

Instructor Outline, Day Three, 10:30 - 3:00

9. Practice squaring of structures using steel stakes at the corners and use instruments to level for stringlines. Show how to attach the stringlines to the stakes.

10. Set up batter boards at each corner of the structure and attach stringlines for the footing and outside of walls.

11. If pouring a slab set the stringlines to desired grade and leave in place for forming.

12. Set up stringlines for line and grade of all class projects.

Section V: Forming For Placement

Instructor Outline Day Three 3:00 - 4:30
Hands-on Exercises

1. Clear project site of debris, sod or any foreign materials in project area.

Forming

2. Setting forms for sidewalk, curb and gutter, footings and slabs on grade. Fine grading after forming is complete. Set up of screeds to fine grade and strike off for large slab. Form up class projects. Oil forms when ready for placement of concrete. The topics listed below should be covered during or previous to the hands-on exercises.

   a. Formwork must be built to withstand the pressures of fluid concrete without bulging or warping. They must be able to hold up under enormous pressures, and pressures caused by vibrating the concrete.

b. Sufficient staking and bracing is necessary to keep the forms true to vertical and horizontal alignment.

c. After the stringlines are squared on the batter boards and excavating is completed, a plumb bob is used to set stringlines which will be used for line and grade of the form.

d. A good grade of lumber must be used for forming, free of knots, and cracks, usually called "construction grade" lumber. Standard sizes of lumber such as 2x4's, 2x6's, 1x4's, and so on are commonly used.

e. Plywood sheathing is universally used for wall forms because it produces a smooth surface and the 4x8 sheets make it very economical. Three-quarter inch thick plywood is most commonly used for forming walls.

f. On large flatwork jobs, such as public walks, steel forms are often used because they can be re-used more often and are faster to set up.

g. Wall forming systems consist of form panels and an assortment of form accessories, such as wall ties, fasteners, spreaders, braces, inserts, etc. While talking about forms and form materials, display these items so the class understands about different lumber grades, forming systems, such as wall form panels or plywood built wall forms, and steel forming systems and accessories.

h. Demonstrate the use of these forming systems, how to handle them, store them, and most important how to clean and oil them.

i. Stress the importance of safety when building forms, especially wall forms where scaffolding may be needed. Safety factors, like good housekeeping, are necessary to prevent tripping hazards, or guard rails on scaffolds to prevent falls.

j. Discuss the use of reinforcing in concrete. Present examples of reinforcement, such as welded wire mesh and different sizes of rebar.

k. Welded wire mesh is available in many sizes, the most common being 5'x150' rolls. The wire spacing and thickness is determined by the type of project, such as warehouse floors, garage slabs, or pavements. The most widely used wire mesh has a 6"x6" wire spacing and 10 gauge wire size. Explain different wire spacing and wire size and where they would be used.

l. Reinforcing bars (rebar) comes in two types, smooth bars and deformed bars, and in different grades or strengths. Smooth rebars are used in contraction joints so the bars are free to slide in the concrete and also provide shear strength across the joint. Deformed rebars are the standard type and are rolled with deformations to provide a good bond with the concrete.

m. Sizes are determined by the rebar number (#) and are sized in eighths of an inch, for example, $1/4$" or $5/8$". Number sizes compare with the one-eighth inch size of the bar. Three-eighths is #3, $3/4$ is #6, 1 $1/8$ is #9 and so on.

n. Show the class examples of wire mesh and rebars and explain where to find the ID marks on rebars and tags on rolls of wire mesh.

Concrete Tools and Equipment

3. Discuss tools and equipment, list and show examples. Explain the use of these tools, when, and where they are used in the concrete construction process.

4. Talk about safety around the different equipment, such as compressors, compactors, etc.

5. Demonstrate the proper use of these tools and equipment whenever they are used throughout the course.

6. Assign pages 68-79 to read as homework.

Concrete Tools and Equipment List

Hand Tools:

Shovels- long & short handles, square & round point
100 foot rag tape
6 foot folding engineer's rule
Plumb bobs
Squares
Levels - line and torpedo
Claw hammers
Sledge hammers
Ice scrapers
Wire brushes
Wrecking bars
Rakes
Form Pin Puller
Pump up sprayer for form oil
Hand saw
Wire pliers
Drift punch
Spud Bar
Cats Paw
Crescent Wrenches

Power Tools:

Immersion vibrator
Compactor
Generator
Concrete Milling Machine
Concrete Saw w/diamond blade

Concrete Tools:

Floats - wood, fiberglass, and magnesium
Edgers - different sizes and radii, hand and walking
Darby - wood or magnesium
Bull float
Groovers/jointers - hand and walking
Steel trowels - various sizes
Broom and brush - for sidewalk and curb finish
Test cylinders
Slump test kit
Come-a-long
Thermometer

Materials:

Concrete (25 cu. yds. delivered)
Lumber - 2x4s & 2x6s of different lengths
Nails - 8d & 12d duplex, 8d & 12d box
2x4 stakes - 18" to 30' long
Steel form stakes (round or square)
String line with steel stakes
Form oil
Expansion Felt
Sono Tube
Wall form panels
Form system accessories
Wall ties
Sidewalk forms
Curb and gutter forms
Rebar - $1/2$"
Visqueen
Curing compound and sprayer
Curing blankets
Concrete repair materials for overlays, crack repair, and patches.

Safety Equipment:

Hard hats
Safety glasses
Ear plugs
Safety belts
Vinegar
Rain gear
Work boots & gloves
Eye wash
First aid kit

Section VI: Placement And Consolidation

Instructor Outline, Day Four, 12:30 to 2:30

1. Review homework or questions from day two.

2. Lecture on Placement.

   a. The most economical source of concrete is Ready-mix delivered to the job in mixer trucks hauling up to 12 cubic yard per load.

   b. Ready mixed concrete is proportioned to the required specifications of each job to ensure desired properties.

   c. Discuss how concrete mixes differ, why different mixes are needed, and where they might be used.

   d. When ordering a concrete mix, we must also order how much we need. Estimate how much concrete will be needed for class projects.

   e. When concrete reaches the job site it must be placed in the forms in a manner that will prevent segregation of the mix.

   f. Some methods of placement include: direct discharge from the mixer truck, crane and bucket, pumps, conveyors, buggies and wheel barrows. The method used will depend on the size of the job, space and equipment available, and the distance of forms from the mix truck.

   g. No matter what method of placement is used, care must be taken to prevent segregation. This can be accomplished by dumping loads of concrete against previously placed loads, the use of drop chutes to reduce free fall of the mix, and preventing concrete from being dropped against forms and reinforcing.

   h. Concrete should be dropped vertically and placed as near its final location as possible to prevent segregation.

   i. In walls and beams concrete should be placed in lifts not to exceed 18 inches and then consolidated. In high, narrow walls, a window or port may be needed to limit free fall of the concrete.

   g. When placing concrete in slabs, batches should be placed against concrete already in place, never dumped in separate piles. When placing concrete on a slope, start at the lowest point and work up the slope.

3. Show film: "Transporting and Placing Quality Concrete (by PCA). Refer to pages 82-85 for questions on film.

4. Lecture on Consolidation.

   a. As concrete is being placed, it must be consolidated to remove entrapped air, reduce rock pockets, and bond the mix to reinforcement.

   b. Consolidation is accomplished by the use of mechanical vibrators. These vibrators can be electric with a flexible shaft and have an internal or external motor. Vibrators can also be air or hydraulic powered. The size of the vibrator will depend on the type of pour and the type of concrete mix being placed.

   c. In walls, beams, and columns the vibrator should be held vertically and as layers are placed, it should penetrate the lower lift 3 to 4 inches to bond the lifts together.

   d. In slabs the vibrator should be moved horizontally through the mix for consistent consolidation.

5. Show film: "Concrete Vibrations", refer to pages 86-87 for questions on film.

6. Lecture on leveling and strikeoff procedures.

   a. The final step in placing concrete is strike-off. Strike-off is the leveling of the surface of the concrete by removing any excess mix above the top of the form. A straight edge is used to strike-off and can be wood or metal.

   b. A vibrating straight edge, or power screed, is commonly used on large slabs to consolidate the mix and provide a flatter surface.

7. Assign pages 88-104 as homework.

"Transporting and Placing Quality Concrete"

Questions on information in the Portland Cement Association film

1. How does the film define the following terms:

   a. Water to cement ratio

   b. Slump

   c. Air content

   d. Uniformity

   e. Consolidation

   f. Specification

   They are used in the film but not closely or adequately defined.

2. How is the term segregation defined?

   The separation of coarse aggregate from the concrete.

3. What happens when a bucket containing concrete is jarred?

   It causes segregation.

4. What distances does the film say concrete has been effectively pumped?

   500' vertically and 2000' horizontally.

5. Why does pumping resist segregation?

   The hose and pumping process confines and compacts the concrete.

6. What does the film say about kinks and bends in pump hose?

   They have to be controlled.

7. What criteria govern aggregate and slump when pumping concrete?

   a. Good gradation of aggregate with the largest aggregate no more than 1/3 the inside diameter of hose or pipe.
   b. Slump between 3 and 4".

8. What does the film recommend in placing concrete in walls, beams, and girders?

   a. Placed continuously in not more than 18" lifts.
   b. Dropped no more than 3 - 4' through rebar or other embedded items.
   c. Batches placed no more than 10' apart in walls.

9. What equipment is used to control segregation when placing concrete in walls?

Drop chutes or elephant trunks.

10. How does the film define the vibration process?

It consolidates the concrete, gets out entrapped air, allowing a mix with less fines and water to be used.

11. What are the 5 points the film makes about forms?

a. Clean
b. Tight
c. Adequately braced
d. Moisten wooden forms
e. Coated with nonstaining recommended form release agent for easy stripping.

12. What rules does the film have for the placement process for slabs? For a slope?

a. Place concrete as close to final position as possible; start a slab pour at one end; place concrete against concrete in place.
b. Start at the bottom of a slope.

13. When does strike off occur? What does strike off accomplish?

a. As soon as possible after placement.
b. It is a leveling process.

14. How does the film say a vibrator should be lowered into concrete?

Vertically, never at haphazard angle.

15. Should concrete be moved with a vibrator? ..... Why not?

a. Don't move concrete with a vibrator.
b. Causes segregation by mortar flowing away from aggregate.

16. What does the film say about slump and vibration?

By using vibration, a lower slump concrete can be placed.

17. What is the rule on vibration of lifts?

Penetrate lower lift 3 or 4".

18. What does the film say vibration does to voids?

Fills the voids with cement paste.

19. What happens when the vibrator is held too long in one place?

It drives aggregate away from the vibrator.

20. When does the film say to stop vibrating?

When a glistening sheen appears on the surface.

21. What is the most effective coolant in the hot weather concrete process?

Ice added as part of the mixing water.

22. What other means are used to control the temperature of concrete prior to delivery at job site?

a. Cooling of aggregate.
b. Spray bars on truck.
c. Early delivery - within 45 minutes to 1 hour.

23. What is another way to control the set of concrete in hot weather?

Sometimes using a retardant.

24. What is the critical temperature point in cold weather placement of concrete?

40 degrees F.

25. How are materials heated for cold weather concreting?

Heat water in boilers, heat aggregate with steam or hot air.

26. What temperature does the concrete need not exceed at job site?

70 degrees F.

27. What is the temperature range that heating of aggregates and water should heat the concrete to when it is ready to be delivered?

45 to 70 degrees F.

28. What does the film say about ice and snow in forms?

Must not be in forms or on rebar at the time of delivery.

29. When is freezing of the concrete a danger?

Until it reaches 500 psi.

30. Which of the processes: delivery, placement, consolidation, finishing, can be slowed down in cold weather?

None. All must be accomplished as rapidly as possible.

"Concrete Vibration"

Questions on information in the Laborers-AGC film

1. Which safety factors does the film discuss?

a. Personal protective equipment ***b. Electrical connections***
c. Scaffold and toe boards ***d. Staying out from under loads.***
e. Watching out for both ends of a conveyor
f. Having help with heavy pump hoses

2. How does this film define segregation?

The separation of the aggregate and the mortar. This is demonstrated by showing what happens when the free fall of concrete is not controlled.

3. What freefall distance does the film recommend?

4 - 6'

4. What are the recommended lifts?

18" in regular mix, 12 - 14" in lightweight concrete

5. How much does the film say to penetrate lifts with the vibrator? Why?

a. 4"
b. To bond the lifts together and to prevent pour lines.

6. What are the signs to determine effective vibration?

a. Liquifies ***b. Levels off***
c. Settles into forms ***d. Entrapped air is released***

7. a. What is meant by "Fields of Action"?

b. How are they overlapped?

a. Field of action is the area a given vibrator can effectively vibrate a given mix in one insertion
b. By a series of immersions each overlapping others

8. What is the distance recommended for immersion points?

12 to 30" apart

9. Why do you slowly withdraw the vibrator in low slump mixes?

To fill in the hole caused by the vibrator

10. What is the time recommended for vibration?

5 to 15 seconds

11. How is the vibrator held?

Vertically (in thin slabs it is permissible to hold at an angle.)

12. What does the concrete do to the vibrator?

It acts to cool the vibrator

13. Why is it recommended to stay away from the forms with the vibrator?

Form damage and extra finishing costs

14. What is the "Rule of Thumb" about vibrating more or less?

When in doubt always vibrate more than less

15. What is important to observe about the forms when vibrating concrete?

Any leaks of mortar and any signs of form failure

16. How should concrete be placed in a deck pour?

    a. ***In beams and joists first***
    b. ***Always against concrete in place***

17. How is segregation prevented in a wall pour?

By controlling free fall, dropping into center of forms, and by keeping vibration under control.

18. What is the recommended procedure in vibrating concrete in beams or walls?

Vibration stays behind so unvibrated concrete forms a dam to pervent mortar running.

Section VII: Finishing And Curing

Instructor Outline, Day Four, 2:30 - 4:30

1. Review homework and questions from day three.

2. Lecture on finishing and curing concrete.

   a. Finishing operations including: edging, jointing, floating, trowelling and brooming. No finishing operations can begin until all bleed water has left the surface of the concrete. Finishing before the water sheen has left the surface will produce a surface with excessive dusting and scaling.

   b. Bull floating must be done immediately following strike off. Bull floats are large wood or metal floats with long handles and are used to level ridges and fill voids left by the straight edge and to embed the coarse aggregate below the surface.

   c. Edging is the first step of the finishing operation. Edging compacts the concrete surface next to the form and provides a neat rounded edge that is resistant to chipping and form removal damage.

   d. Jointing operations begin during or immediately after edging and are the most important finishing operations. Joints are tooled into the concrete surface to provide a weakened section so cracks occur beneath the joint and not randomly across the slab.

   e. Joints should extend one-fifth to one-fourth of the way into the slab thickness to be effective. These joints are called control joints or contraction joints.

   f. Control joints in driveways and sidewalks should be spaced equal to the width of the slab and no more than 12 feet apart.

   g. The jointer or groover should be guided by a straight edge to produce a straight joint and provide a platform for the finisher.

   h. Other joints necessary when pouring slabs are isolation, or expansion joints, and construction joints.

   i. Isolation or expansion joints are needed where slabs meet existing structures such as buildings or manholes. They provide for expansion of the concrete and provide for slab movement to eliminate stress cracking.

   j. Construction joints are required where the placement ends temporarily and will continue after the concrete has hardened. They should be located to act as control joints. A key way must be used to ensure the two slabs stay level with each other.

   k. After edging and jointing the surface is hand floated. This floating is done for three purposes: to embed aggregate below the surface; to remove imperfections

and edger and jointer marks; and, to compact and consolidate mortar at the surface.

l. Troweling or brooming are the last finishing steps. Troweling provides a hard, dense, smooth surface and brooming provides a roughened skid resistant surface.

m. Hardening of concrete is a chemical reaction between water and cement. This process is called hydration. This process will stop unless proper moisture and temperature is maintained.

o. Curing of concrete is the process used to maintain these conditions by keeping it moist and warm.

p. Curing can be done using water to pond or sprinkle onto wet coverings that will maintain the moisture necessary for hydration. Burlap is the most common wet covering.

q. Sealing the finished surface with plastic sheeting or waterproof paper can be used for curing, but care must be taken to seal the joints and prevent wrinkles which would allow the concrete to dry out.

r. Sprayed on curing compounds provide the easiest and most convenient curing. The surface should be damp when curing compounds are applied. Complete coverage is essential.

s. Curing during cold weather is accomplished by the use of insulated blankets or straw that is covered with canvas or plastic sheeting to keep it dry. Temperature must be kept above 40° F. for 5 days for the concrete to set properly.

t. Curing during hot weather can be aided by dampening the subgrade and forms, putting up wind screens and sun shades, cutting down on finishing time or temporary wet coverings.

3. Show film: "Finishing and Curing Quality". Refer to pages 106-108 for questions on the film.

4. Assign pages 109-114 as homework.

Instructor Outline Day Five, 8:00 - 12:00
Hands-on Exercises

5. Place, consolidate, finish, and cure class projects. Bull floating, edging, grooving and floating of sidewalk, curb and gutter and slabs. Troweling of slabs. Brush finish on sidewalk and curb and gutter. Spray curing of slab, sidewalk and curb and gutter; water curing of slab.

6. Clean up from pour #1.

"Finishing and Curing Quality Concrete"

Questions on information in the Portland Cement Association film

1. What 2 variables must be controlled to get optimum hydration?

   Sufficient moisture and favorable temperatures for hydration

2. What does the film recommend about form removal?

   Forms should be eased away from the concrete

3. What is done after the forms are removed?

   Fins and projections are ground away, holes are filled, and the surface wet rubbed

4. What are the timing and/or strength factors for abrasive finishing?....bush hammering finishing?
   a. 24 - 72 hours ***b. 3750 psi***

5. What 4 methods are used in the exposed aggregate finishing process?

   Washing, brooming, chemical retarding, abrasive blasting, tooling.

6. Are strike off and bullfloating part of the finishing process?

   No. They are part of the placement process

7. What 2 criteria are used to determine when to start the finishing process?

   Bleed water has disappeared and concrete will withstand foot pressure with only a slight indentation

8. What is the recommended technique for using the edging tool? What does edging accomplish?

   a. Front edge slightly raised
   b. The rounded edge resists chipping and other damage

9. What is good procedure in keeping a control joint to line and grade?

   Guide the tool with a straight edge

10. What does a control joint actually do?

    Provides a weakened section where cracks can form

11. What is the finishing process called that follows edging and control jointing?...Can this process be done by machine?

    a. Floating
    b. Either by hand or by machine

12. What 3 things does floating do?

    a. ***Cuts out ridges and fills in voids***
    b. ***Provides slip resistant and slightly gritty surface***
    c. ***Consolidates mortar at surface for further finishing***

13. What immediately follows floating in the finishing process? When does this take place?

    a. ***Troweling***
    b. ***Immediately after floating***

14. Can troweling take place before the floating is done?...What does troweling do?

    a. ***Surface has to be floated before troweling***
    b. ***Steel trowel for hard dense surface.***

15. What is the recommendation on tool size and techniques with first troweling?

    Flat trowel with large trowel and overlap each circular pass by one half with next pass.

16. What happens when sufficient troweling takes place?

    A ringing sound with the troweling

17. When is a concrete surface broomed?...Should the broom be wet or dry?

    a. ***Either after floating or troweling***
    b. ***Wet***

18. What does the film recommend about sawing joints in concrete?

    Joints should be sawed as soon as surface is firm enough not to be damaged by the blade.

19. What does the curing process do to concrete?

    Provides sufficient moisture at proper temperature for optimum hydration

20. What is the best method for curing concrete?...Can this process be intermittent?

    a. ***With water***
    b. ***Providing the water cure is continuous***

21. What are 3 different methods used to water cure?

    a. ***Ponding***
    b. ***Spraying***
    c. ***Wet burlap or rugs***

22. Can other natural materials be used for curing?...What should be determined before using these materials?

    a. ***Wet earth, sand, sawdust and straw***
    b. ***They should be non-staining***

23. What does a sealant do to the concrete?...What are 3 kinds of sealants?

    a. They prevent evaporation of the mix water
    b. Waterproof paper, visqueen, curing compounds

24. What are the 2 types of curing compounds?

    Pigmented and clear

25. What are 2 requirements when using a curing compound?

    Damp surface and complete coverage

26. How long should forms remain on the concrete?...When forms are on walls, what additional curing process does the film recommend?

    a. As long as possible
    b. Keep upper surface wet

27. What temperature does the film recommend keeping concrete at in cold weather?

    50 degrees F.

28. What 5 methods does the film discuss to control temperature during cold weather concreting?

    a. Straw
    b. Insulation blankets and sheets
    c. Enclosures with portable heating units
    d. Heating electrically through wires attached to rebars
    e. Steam curing

Section VIII: Form Stripping And Clean-up

Instructor Outline, Day Five, 12:30 - 1:30

1. Show video "Housekeeping -- The Winning Ticket"

2. Lecture on safe stripping and clean up procedures

   a. Form removal will be determined by the strength of the concrete and curing requirements.

   b. When removing forms, care must be taken not to damage the concrete surface or the face of the form

   c. After forms are removed they should be inspected for any damage and cleaned of all hardened concrete.

   d. Wall forms should be oiled when they are cleaned so the oil soaks in before they are set up again. This is true for all wood forms. Steel forms should be oiled after they are set up.

   e. When storing forms, be sure they are stacked straight and on a level surface to prevent warping or twisting.

   f. Good housekeeping practices at the construction site are necessary to prevent tripping and falling hazards.

   g. All scrap lumber and material containers should be cleaned up continuously to provide a safe work area. Nails should be bent flat or removed from all scrap or forming lumber.

   h. A clean, well kept construction site will make everyone's job easier, and will provide better safety inspections and a smoother job atmosphere.

Assign pages 116-117 as homework.

Section IX: Concrete Admixtures

Instructor Outline, Day Five, 1:30 - 4:30

1. Discuss the need for admixtures in concrete. Explain what an admixture is and the effect they have on concrete before and after setting.

2. Discuss the following types of admixtures:

Air Entrainers	Plasticizers
Retarders	Accelerators
Pozzolans	

Instructor Outline, Day Six, 8:00 - 9:00
Hands-on Exercises

1. Remove forms from class projects, clean forms with scrapers and wire brushes. Stack forms in storage area.

Instructor Outline, Day Six, 9:00 - 4:30
Hands-On Exercises

1. Practice wall form set ups, leave forms ready for placement.
2. Form columns for second placement exercise.
3. Form slab for second placement exercise.
4. Practice squaring, volume calculations, and elevation control.

Instructor Outline, Day Seven, 8:00 - 12:00
Hands-On Exercises

5. Place concrete using pump in exercises formed during day six.
6. Finish, cure, and clean up.

Section X: Sawing Concrete

Instructor Outline, Day Seven, 12:30 - 1:30

1. Laborer-AGC video "Concrete Saws"
2. Discuss and review Training TIPS #6 on concrete saws.
3. Explain the need for sawing concrete: when, depth, and location of saw cuts for different structures.
4. Discuss with trainees that sawing is another form of control joint to prevent random cracking of slabs, walks, driveways, floors, etc.

Section XI: Concrete Repair and Rehabilitation

Instructor Outline, Day Seven, 1:30 - 4:30

1. Discuss different types of concrete repair including:

    a. Pavement Repair - full depth patches
    - partial depth patches

    b. Overlays for surface repair of bridge decks and floors.

    c. Crack and joint repair

2. Discuss surface preparation for all repair types listed above.

3. Discuss materials used for the different types of repairs.

4. Discuss placement of repair material, tools, and equipment needed.

5. Discuss finishing and curing of repair areas.

Instructor Outline, Day 8, 8:00 - 10:00
Hands-On Exercises

1. Concrete Sawing Demonstration.

2. Demonstration should include maintenance checks and blade installation. Stress importance of straight cuts and how to align the saw to make a cut. To practice saw alignment, stop sawing part-way across the slab and have trainees move and re-align the saw to finish the cuts.

3. Concrete Repair Demonstration

4. Demonstration should include set up, surface preparation, finishing and curing of repairs.

Instructor Outline, Day 8, 10:00 - 4:30
Hands-On Exercises

5. Continue repair and sawing practice exercises.

Instructor Outline, Day 9, 8:00 - 4:30
Hands-On Exercises

6. Strip, clean, oil and store forms from second placement.

7. Continue sawing and surface preparation.

8. Begin repair placement exercises, include overlay, horizontal and vertical cracks, and damaged concrete replacement.

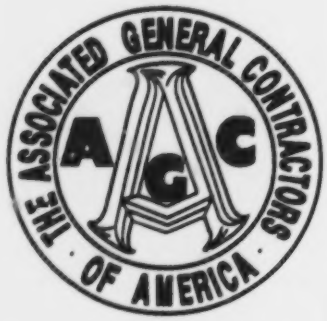
Instructor Outline, Day 10, 8:00 -12:00
Hands-On Exercises

9. Complete concrete repair exercises.

Instructor Outline, Day 10, 12:30 - 4:30
Hands-On Exercises

10. Site clean-up and equipment and material storage.

11. Review and evaluation.



Concrete Practices & Procedures

A

Trainee Manual

by

Laborers-AGC

Education and Training Fund

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James M. Warren, Director

Version 9/90

SECTION I: SAFETY

Pages 2 - 6	Federal Register Subpart Q - Concrete and Masonry Construction
Page 7	Questions on Film: *Working at Heights Safely*
Pages 8 - 9	Article 1: *Developing Construction Safety Awareness*
Page 10	Article 2: *Reduce Back Injuries by Lifting Correctly*
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Pages 14 - 17	Article 4: *Worker Safety In Formwork Operations*
Pages 18 - 20	Article 5: *The Burning Facts of Cement*

Trainee Section Objectives

1. Become familiar with the U. S. Federal OSHA regulation Subpart Q concerning Concrete and Masonry Construction.
2. Develop a construction safety attitude and awareness.
3. Become aware of incorrect lifting procedures and learn the correct methods.
4. Become aware of the safety hazards associated with trenching and excavation operations.
5. Become aware of the safety hazards associated with concrete formwork operations.
6. Become aware of the skin irritations and conditions caused by contact with concrete and cement.

FEDERAL REGISTER
PART II
DEPARTMENT OF LABOR
Occupational Safety and Health Administration

29 CFR Part 1926
Concrete and Masonry Construction
Safety Standards; Final Rule

Subpart Q-Concrete and Masonry Construction

Sec. 1926.700	Scope, application and definitions applicable to this subpart.
1926.701	General requirements.
1926.702	Requirements for equipment and tools.
1926.703	Requirements for cast-in-place concrete.
1926.704	Requirements for precast concrete.
1926.705	Requirements for lift-slab operations.
1926.706	Requirements for masonry construction.

Appendix A to Subpart Q-References to Subparts of Part 1926

Subpart Q-Concrete and Masonry Construction
Authority: Sec. 107. Contract Work Hours and Safety Standards Act (Construction Safety Act) (40 U.S.C. 333); Secs. 4, 6, and 8, Occupational Safety and Health Act of 1970 (29 U.S.C. 653, 655, and 657); Secretary of Labor's Order No. 12-71 (36 FR 8754), 8-76 (41 FR 25059) or 9-83 (48 FR 3538), as applicable; and 29 DFR Part 1911.

1926.700 Scope, application, and definitions applicable to this subpart.
(a) Scope and application. This subpart sets forth requirements to protect all construction employees from the hazards associated with concrete and masonry construction operations performed in workplaces covered under 29 CFR Part 1926. In addition to the requirements in Subpart Q, other relevant provisions in Parts 1910 and 1926 apply to concrete and masonry construction operations.
(b) Definitions applicable to this subpart. In addition to the definitions set forth in 1926.32, the following definitions apply to this subpart.
(1) "Bull float" means a tool used to spread out and smooth concrete.
(2) "Formwork" means the total system of support for freshly placed or partially cured concrete, including the mold or sheeting (form) that is in contact with the concrete as well as all supporting members including shores, reshores, hardware, braces, and related hardware.
(3) "Lift slab" means a method of concrete construction in which floor, and roof slabs are cast on or at ground level and, using jacks, lifted into position.
(4) "Limited access zone" means an area alongside a masonry wall, which is under construction, and which is clearly demarcated to limit access by employees.
(5) "Precast concrete" means concrete members (such as walls, panels, slabs, columns, and beams) which have been formed, cast and cured prior to final placement in a structure.
(6) "Reshoring" means the construction operation in which shoring equipment (also called reshores or reshoring equipment) is placed as the original forms and shores are removed, in order to support partially cured concrete and construction loads.
(7) "Shore" means a supporting member that resists a compressive force imposed by a load.
(8) "Vertical slip forms" means forms which are jacked vertically during the placement of concrete.

1926.701 General requirements
(a) Construction loads. No construction loads shall be placed on a concrete structure or portion of a concrete structure unless the employer determines, based on information received from a person who is qualified in structural design, that the structure or portion of the structure is capable of supporting the loads.
(b) Reinforcing steel. All protruding reinforcing steel, onto and into which employees could fall, shall be guarded to eliminate the hazard of impalement.
(c) Post-tensioning operations. (1) No employee (except those essential to the post-tensioning operations) shall be permitted to be behind the jack during tensioning operations.
(2) Signs and barriers shall be erected to limit employee access to the post-tensioning area during tensioning operations.
(d) Riding concrete buckets. No employee shall be permitted to ride concrete buckets.
(e) Working under loads. (1) No employee shall be permitted to work under concrete buckets while buckets are being elevated or lowered into position.
(2) To the extent practical, elevated concrete buckets shall be routed so that no employee, or the fewest number of employees, are exposed to hazards associated with falling concrete buckets.

(f) Personal protective equipment. (1) No employee shall be permitted to apply a cement, sand and water mixture through a pneumatic hose unless the employee is wearing protective head and face equipment.
(2) No employee shall be permitted to place or tie reinforcing steel more than six feet (1.8m) above any adjacent working surface unless the employee is protected by the use of a safety belt or equivalent fall protection meeting the criteria of Subpart E of this part.

1926.702 Requirements for equipment and tools
(a) Bulk cement storage. (1) Bulk storage bins, containers and silos shall be equipped with the following:
(i) Conical or tapered bottoms; and
(ii) Mechanical or pneumatic means of starting the flow of material.
(2) No employee shall be permitted to enter storage facilities unless the ejection system has been shut down, locked out, and tagged to indicate that the ejection system is not to be operated.
(b) Concrete mixers. Concrete mixers with one cubic yard (.8m) or larger loading skips shall be equipped with the following:
(1) A mechanical device to clear the skip of materials; and
(2) Guardrails installed on each side of the skip.
(c) Power concrete trowels. Powered and rotating type concrete troweling machines that are manually guided shall be equipped with a control switch that will automatically shut off the power whenever the hands of the operator are removed from the equipment handles.
(d) Concrete buggies. Concrete buggy handles shall not extend beyond the wheels on either side of the buggy.
(e) Concrete pumping systems. (1) Concrete pumping systems using discharge pipes shall be provided with pipe supports designed for 100 percent overload.
(2) Compressed air hoses used on concrete pumping system shall be provided with positive fail-safe joint connectors to prevent separation of sections when pressurized.
(f) Concrete buckets. (1) Concrete buckets equipped with hydraulic or pneumatic gates shall have positive safety latches or similar safety devices installed to prevent premature or accidental dumping.
(2) Concrete buckets shall be designed to prevent concrete from hanging up on top and the sides.
(g) Tremies. Sections of tremies and similar concrete conveyances shall be secured with wire rope (or equivalent materials in addition to the regular couplings or connections.
(h) Bull floats. Bull float handles, used where they might contact energized electrical conductors, shall be constructed of nonconductive material or insulated with a nonconductive sheath whose electrical and mechanical characteristics provide the equivalent protection of a handle constructed of nonconductive material.
(i) Masonry saws. (1) Masonry saws shall be guarded with a semicircular enclosure over the blade.
(2) A method for retaining blade fragments shall be incorporated in the design of the semicircular enclosure.
(j) Lockout/Tagout Procedures. (1) No employee shall be permitted to perform maintenance or repair activity on equipment (such as compressors, mixers, screens or pumps used for concrete and masonry construction activities) where the inadvertent operation of the equipment could occur and cause injury, unless all potentially hazardous energy sources have been locked out and tagged.
(2) Tags shall read DO NOT START or similar language to indicate that the equipment is not to be operated.

1926.703 Requirements for cast-in-place concrete.
(a) General requirements for formwork. (1) Formwork shall be designed, fabricated, erected, supported, braced and maintained so that it will be capable of supporting without failure all vertical and lateral loads that may reasonably be anticipated to be applied to the formwork, Formwork which is designed, fabricated, erected, supported, braced and maintained in conformance with the Appendix to this section will be deemed to meet the requirements of this paragraph.
(2) Drawings or plans, including all revisions, for the jack layout, formwork (including shoring equipment), working decks, and scaffolds, shall be available at the job site.
(b) Shoring and reshoring. (1) All shoring equipment (including equipment used in reshoring operations) shall be inspected prior to erection to determine that the equipment meets the requirements specified in the formwork drawings.
(2) Shoring equipment found to be damaged such that its strength is reduced to less than that required by 1926.703(a)(1) shall not be used for shoring.
(3) Erected shoring equipment shall be inspected immediately prior to, during, and immediately after concrete placement.

(4) Shoring equipment that is found to be damaged or weakened after erection, such that its strength is reduced to less than that required by 1926.703(a)(1) shall be immediately reinforced.
(5) The sills for shoring shall be sound, rigid, and capable of carrying the maximum intended load.
(6) All base plates, shore heads, extension devices, and adjustment screws shall be in firm contact, and secured when necessary, with the foundation and the form.
(7) Eccentric loads on shore heads and similar members shall be prohibited unless these members have been designed for such loading.
(8) Whenever single post shores are used one on top of another (tiered), the employer shall comply with the following specific requirements in addition to the general requirements for formwork:
(i) The design of the shoring shall be prepared by a qualified designer and the erected shoring shall be inspected by an engineer qualified in structural design.
(ii) The single post shores shall be vertically aligned.
(iii) The single post shores shall be spliced to prevent misalignment.
(iv) The single post shores shall be adequately braced in two mutually perpendicular directions at the splice level. Each tier shall also be diagonally braced in the same two directions.
(9) Adjustment of single post shores to raise formwork shall not be made after the placement of concrete.
(10) Reshoring shall be erected, as the original forms and shores are removed, whenever the concrete is required to support loads in excess of its capacity.
(c) Vertical lip forms. (1) The steel rods or pipes on which jacks climb or by which the forms are lifted shall be-
(i) Specifically designed for that purpose; and
(ii) Adequately braced where not encased in concrete.
(2) Forms shall be designed to prevent excessive distortion of the structure during the jacking operation.
(3) All vertical slip forms shall be provided with scaffolds or work platforms where employees are required to work or pass.
(4) Jacks and vertical supports shall be positioned in such a manner that the loads do not exceed the rated capacity of the jacks.
(5) The jacks or other lifting devices shall be provided with mechanical dogs or other automatic holding devices to support the slip forms whenever failure of the power supply or lifting mechanism occurs.
(6) The form structure shall be maintained within all design tolerances specified for plumbness during the jacking operation.
(7) The predetermined safe rate of lift shall not be exceeded.
(d) Reinforcing steel. (1) Reinforcing steel for walls, piers, columns, and similar vertical structures shall be adequately supported to prevent overturning and to prevent collapse.
(2) Employers shall take measures to prevent unrolled wire mesh from recoiling. Such measures may include, but are not limited to, securing each end of the roll or turning over the roll.
(e) Removal of formwork. (1) Forms and shores (except those used for slabs on grade and slip forms) shall not be removed until the employer determines that the concrete has gained sufficient strength to support its weight and superimposed loads. Such determination shall be based on compliance with one of the following.
(i) The plans and specifications stipulate conditions for removal of forms and shores, and such conditions have been followed, or
(ii) The concrete has been properly tested with an appropriate ASTM standard test method designed to indicate the concrete compressive strength, and the test results indicate that the concrete has gained sufficient strength to support its weight and superimposed loads.
(2) Reshoring shall not be removed until the concrete being supported has attained adequate strength to support its weight and all loads in place upon it.

Appendix to 1926.703(a)(1) (This Appendix is non-mandatory.)
This appendix serves as a non-mandatory guideline to assist employers in complying with the formwork requirements in 1927.703(a)(1). Formwork which has been designed, fabricated, erected, braced, supported and maintained in accordance with Sections 6 and 7 of the American National Standard for Construction and Demolition Operations-Concrete and Masonry Work, ANSI A10.9-1983, shall be deemed to be in compliance with the provision of 1926.703(a)(1).
(Information collection requirements contained in paragraph (a)(2) were approved by the Office of Management and Budget under control number 1218-0095)

1926.704 Requirements for precast concrete.
(a) Precast concrete wall units, structural framing, and tilt-up wall panels shall be adequately supported to prevent overturning and to prevent

collapse until permanent connections are completed.
(b) Lifting inserts which are embedded or otherwise attached to tilt-up precast concrete members should be capable of supporting at least two times the maximum intended load applied or transmitted to them
(c) Lifting inserts which are embedded or otherwise attached to precast concrete members, other than the tilt-up members, shall be capable of supporting at least four times the maximum intended load applied or transmitted to them.
(d) Lifting hardware shall be capable of supporting at least five times the maximum intended load applied or transmitted to the lifting hardware.
(e) No employee shall be permitted under precast concrete members being lifted or tilted into position except those employees required for the erection of those members.

1926.705 Requirements for lift-slab operations.
In addition to the general requirements of this Subpart, employers engaged in lift-slab operations shall comply with the existing specific requirements for lift-slab operations which are prescribed in ANSI A10.9-1970. These requirements, found in Section 11 of the American National Standard Safety Requirements for Concrete Construction and Masonry Work, ANSI A10.9-1970, are reprinted in the Appendix to this section. In addition there are applicable requirements in 1928.305(a) and (b) of the Construction Safety and Health Standards which apply to jacks in general, and jacks used specifically in lift-slab construction.

Appendix to 1926.705-Lift-Slab Operations (Reprinted from ANSI A10.9-1970) (This Appendix is mandatory)

Section 11. Lift-Slab Operations
11.1 General. The safety requirements and recommendations in Section 11 apply specifically to lift-slab construction operations.
11.2 Design and Planning. Lift-slab operations shall be designed and planned by a qualified professional engineer or architect. Such plans and designs shall include detailed instructions and sketches indicating the prescribed method of erection.
11.3 Jacking Equipment
11.3.1 Jacking equipment shall not be loaded beyond its safe working capacity, and then threaded rods and other members that transmit loads to the jacks shall have a minimum safety factor of 2.5. Jacking equipment used in lift-slab operations shall meet the criteria in 11.3.1 through 11.3.4. (Note:ANSI has interpreted this provision to mean that the safety factor of 2.5 must be met for all jacking components such as jacks, threaded rods, lifting nuts, lifting angles, as well as shearheads, columns and footings).
11.3.2 Jacks shall be so designed and installed so that they will not continue to lift when overloaded.
11.3.3 Jacks shall be installed with a safety device which will enable them to continue to support the load in any position should the jack malfunction and lose its lifting ability.
11.3.4 The maximum number of manually controlled jacks on one slab shall be limited to 14, and in no event should the number be too great to permit the operator to maintain the slab level within specified tolerances.
11.4 Uniform Lifting. Jacking operations shall be synchronized in such a manner as to insure even and uniform lifting of the slab. During lifting, all points of the slab support shall be kept within one-half inch of that needed to maintain the slab in a level position. If leveling is automatically controlled, a device shall be installed which will stop the operation when the one-half inch tolerance is exceeded or when there is a malfunction in the jacking system. If level is maintained by manual controls, such controls shall be located in a central location and attended by a trained operator while lifting is in progress.
11.5 Falling Hazard. No one shall be permitted under the slab during jacking operations. (Note: ANSI has interpreted this provision as follows: "No one is permitted in the building during jacking operations except those employees required for the jacking operation and to secure slabs.

1926.706 Requirements for masonry construction.
(a) A limited access zone shall be established whenever a masonry wall is being constructed. The limited access zone shall conform to the following.
(1) The limited access zone shall be established prior to the start of construction of the wall.
(2) The limited access zone shall be equal to the height of the wall to be constructed plus four feet, and shall run the entire length of the wall.
(3) The limited access zone shall be established on the side of the wall which will be unscaffolded.
(4) The limited access zone shall be restricted to entry by employees actively engaged in constructing the wall. No other employees shall be permitted to enter the zone.
(5) The limited access zone shall remain in place until the wall is adequately supported to prevent overturning and to prevent collapse unless the

height of wall is over eight feet, in which case, the limited access zone shall remain in place until the requirements of paragraph (b) of this section have been met.

(b) All masonry walls over eight feet in height shall be adequately braced to prevent overturning and to prevent collapse unless the wall is adequately supported so that it will not overturn or collapse. The bracing shall remain in place until permanent support elements of the structure are in place.

Appendix A to Subpart Q-References to Subpart Q of Part 1926

(This Appendix is non-mandatory)

The following non-mandatory references provide information which can be helpful in understanding and complying with the requirements contained in Subpart Q.

- Accident Prevention Manual for Industrial Operations; Eighth Edition; National Safety Council.
- Building Code Requirements for Reinforced Concrete (ACI 318-83).
- Formwork for Concrete (ACI SP-4).
- Recommended Practice for Concrete Formwork (ACI 347-78).
- Safety Requirements for Concrete and Masonry Work (ANSI A10.9-1983).
- Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens (STM C39-66).
- Standard Test Method for Making and Curing Concrete Test Specimens in the Field (ASTM C31-85).
- Standard Test Method for Penetration Resistance of Hardened Concrete (ASTM C803-82).
- Standard Test Method for Compressive Strength of Concrete Cylinders Cast In-Place in Cylindrical Molds (ASTM C873-85).
- Standard Method for Developing Early Age Compressive Test Values and Projecting Later Age Strengths (ASTM C 918-80).
- Recommended Practice for Inspection and Testing Agencies for Concrete, Steel and Bituminous Materials as Used in Construction (ASTM C320-77).
- Method of Making and Curing Concrete Test Specimens in the Laboratory (ASTM C192-88).
- Methods of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete (ASTM C42-87).
- Methods of Securing, Preparing and Testing Specimens from Hardened Lightweight Insulating Concrete for Compressive Strength (ASTM C513-86).
- Test Method for Comprehensive Strength of Lightweight Insulating Concrete (ASTM C495-86).
- Method of Making, Accelerating Curing, and Testing of Concrete Compression Test Specimens (ASTM C884-81).
- Test Method for Compressive Strength of Concrete Using Portions of Beams Broken in Flexure (ASTM C116-88(1980)).

Questions on the film: "Working at Heights Safely"

1. What are the five areas of priority dangers presented in the film?

   a. _____ *b.* _____
   c. _____ *d.* _____
   e. _____

2. How much weight should a scaffold be able to support? _____

3. At what distances should a scaffold be secured to a structure? (Vertically and horizontally)

   _____

4. How much weight should cable on a swinging scaffold support? _____

5. How should the testing of swinging scaffold be done? _____

   _____

6. What is the proper angle ratio for placement of ladders? And how far above the landing should a ladder extend? _____

7. Should loads be carried on ladders? _____

8. What do guard rails consist of? _____

9. If guard rail is temporarily removed, what should be done? _____

10. How should floor openings be protected? _____

11. Distance between a hoist and building should be_____ or_____ .

12. What personal protective equipment was used in the film pertaining to working at heights safety?

    _____

13. When should extraordinary safety precautions be used when working at heights?

    a. _____ *b.* _____
    c. _____ *d.* _____
    e. _____

Article 1: Developing Construction Safety Awareness

Corporate programs centered on the individual worker

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Construction is one of out most hazardous industries. Injuries, illnesses, and fatalities in construction are 54% higher than the national average for all industries. Accidents in the $137-billion industrial, utility, and commercial construction market recently cost $8.9 billion, or 6.5% of the total annual construction dollars (Ref. 1). This clearly indicates, putting aside humanitarian interests and legal obligations, that it makes good business sense to study the causes of accidents and ways to prevent them.

The costs cited are totals including both direct and indirect items. The direct costs include:

- Workers' compensation
- Liability
- Property damage

Indirect costs of accidents include a number of factors such as:

- Loss of productivity
- Disrupted construction schedules
- Administrative time for investigation and reports
- Training of replacement personnel
- Wages to injured workers and other workers for time not worked
- Cleanup and repair
- Adverse publicity
- Third party liability claims
- Equipment damage

These indirect costs are estimated to be from 4 to 17 times as large as the direct costs. With the stakes so high, both large and small construction companies should make a serious effort to improve their safety records. Some methods we have found helpful are described here.

The Safety Handbook

Our company has been in the formwork business for many years and knows the hazards of formwork. We have prepared a handbook specifically outlining many of the formwork hazards. We give a copy to all new employees and ask them to indicate that they have read and understood the material by signing a statement to this effect. Admittedly this does not guarantee that all employees have read and understood the material, but it does help with many new employees.

Meetings and Posters

Another useful way of pointing out safety problems is through weekly safety meetings on the job. Although these meetings usually last only about 5 minutes, we can discuss a wide range of topics concerning safety on a particular project. This is a more direct form of communication and is probably more effective.

Figure 1-1

Safety posters in the job trailer and inside gang tool boxes (Figure 1-1) can serve as reminders if they are noticed after they are initially put up. Changing a poster regularly is more effective than leaving the same one in place for a long time.

Safety Awards

If your work crew is steady or if the job you are working on will last a long time, individual safety awards can be used. Items such as caps, T-shirts, belt buckles, pocket knives, and safety shoes can be used as awards for various lengths of time worked without an accident. Our company uses a 3-month period.

Individual safety awards are good, but they cause the employees to look out only for themselves. Another concept that can be used effectively is the group safety award. With this idea a job or crew on the job, depending on the size of the job, can earn an award by having no accidents for a certain period. These awards can include coffee and doughnuts at break, hamburgers or chicken for lunch, or maybe a little get-together after hours. The advantage of this type of plan is that the newly hired are carefully looked after, especially if it's only a short time before the award is to be received.

Motivating the Foreman

Motivating workers to work safely on their own is one thing; motivating the foreman to make sure that workers work safely is another. Regular foreman safety meetings in which any previous accidents are discussed and where safety ideas and techniques are once again re-emphasized can be effective. Safety awards to the foremen for meeting specific safety goals on the job can also be used.

Cost of Safety Programs

There are problems associated with safety programs. Records must be kept to determine who is eligible for an award, and when. This becomes even more difficult in construction where a worker may work intermittently on your jobs. There is also the problem of purchasing, distributing, and storing the awards. Once the awards arrive at the jobsite, it appears that everyone, whether your employee or not, wants one. Control of the awards must be maintained if they are to mean anything.

Safety programs of any sort cost money. Measuring the effectiveness of a safety program after it has been in effect for some time is difficult. How can you calculate the amount of money saved because of an accident that didn't happen?

A commitment to safety

A safe work place requires more than just luck; a commitment must be made by workers and management at all levels. Prudent managers will make the commitment, not just for humanitarian reasons nor because safety is mandated by law, but also because a good safety program makes sense in terms of dollars and cents.

References

1. "Improving Construction Safety Performance," Report A-3, Construction Industry Cost Effectiveness Project, The Business Roundtable, 200 Park Avenue, New York, New York, January 1982.
2. Hurd, M.K., Formwork for Concrete,SP-4, Fourth Edition, American Concrete Institute, Detroit, Michigan, 1981.
3. Jurewicz, Raymond A., "Worker Safety in Formwork Operations," Concrete Construction, March 1988, page 303-10

Article 2: Reduce Back Injuries By Lifting Correctly

Back injuries are costly. Workers pay the highest price, enduring pain and coping with disabling effects. The employer pays too, for workers' compensation claims, increased insurance rates, and lost productivity. Because many back injuries are caused by lifting, the costs can be reduced by showing workers how to avoid lifting mistakes.

Common Lifting Mistakes
The first mistake is assuming that back injuries are caused by a single lift. Common back disorders are more likely to be caused by improper lifting performed over a period of time. Picking up rebar, bags of cement, or other heavy loads the wrong way, day after day, increases the chances for injury even though pain may not set in for years. Because there's no pain, some workers ignore advice about lifting and repeatedly make the same mistakes. But they pay the price years later.

Other mistakes are in the mechanics of lifting. Most poor lifting methods put strain on the back instead of the legs. These are the most common mistakes:

- Bending the back forward and keeping legs straight during lifting. This puts lots of stress on the lower back.
- Bending and twisting at the same time. This too puts maximum stress on the lower back. It doesn't allow you to pivot the feet or squat to lift.
- Using fast, jerking motions.
- Handling the load too far from your body. With an object at arm's length, stress on the back increases 7 to 10 times.
- Trying to lift a load that's too heavy. Even the right lifting methods won't help if the object is too heavy to be lifted safely.

Lifting The Right Way
Test the load before lifting. If it's too heavy, get help or use a forklift or other lifting device.

Plan each lift. Check the area to make sure there's enough room to lift, a clear path for carrying the load, and a cleared space for putting it down.

Use a shoulder-width, balanced stance with one foot ahead of the other. Keep the lower back in its normal arched position while lifting and bring the load as close to the body as possible. Bending at the knees or dropping to one knee helps get the load close (see Figure 1-2). Keep head and shoulders up and tighten stomach muscles as the lifting motion begins. Lift with the legs and stand up in a smooth, even motion. To change directions, move the feet (pivot) instead of twisting.

Remember, poor lifting habits may not cause discomfort immediately, but the effects do add up. Each wrong-way lift is a deferred pain.

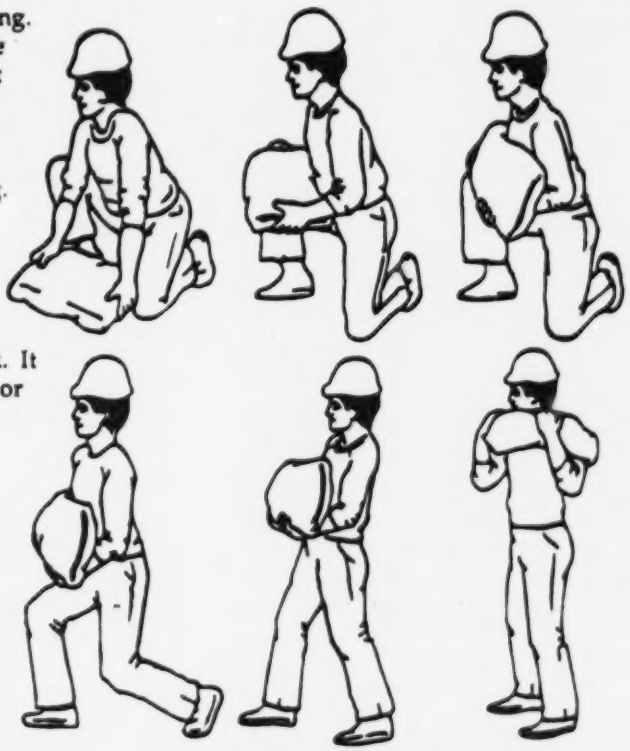

Figure 1-2

Article 3: Trenching Safety for Concrete Contractors

How to recognize hazardous trenching conditions
by: Donn Falls
Safety Director
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Gaithersburg, MD

Adapted to 1989 OSHA regulations by
Laborers-AGC

Every year in the United States, more than 100 people are killed in trench cave-ins. Most of these accidents happen on smaller jobs in excavations less than 20 feet deep. And in some cases, the workers may not have realized that they were working in a trench. Trenches aren't limited to those dug for sewer lines or utility cables. Construction of a basement wall or a sidewall for a culvert creates a trench if the distance from the face of an excavation to the outside of a form or wall is less than 15 feet. Even if the excavation is only 5 feet deep, a cave-in can kill or maim workers setting forms, placing concrete, stripping forms, placing drain tiles or waterproofing walls.

Why Trenching Can Be Deadly
A cubic yard of undisturbed soil weighs about 2700 pounds, the weight of a Volkswagen. When cave-ins occur, the material falls at speeds up to 35 miles per hour.

Usually it pulls away at the top and falls across to the other side, crushing victims between the collapsing soil and the opposite wall of the trench.

Clay is one of the most dangerous materials because it appears to be solid and stable, even when the trench faces are nearly vertical. However, clay is dramatically affected by the weather. Water causes it to swell, drying causes it to shrink, and pressure causes it to bulge. All of these conditions can cause trench failure.

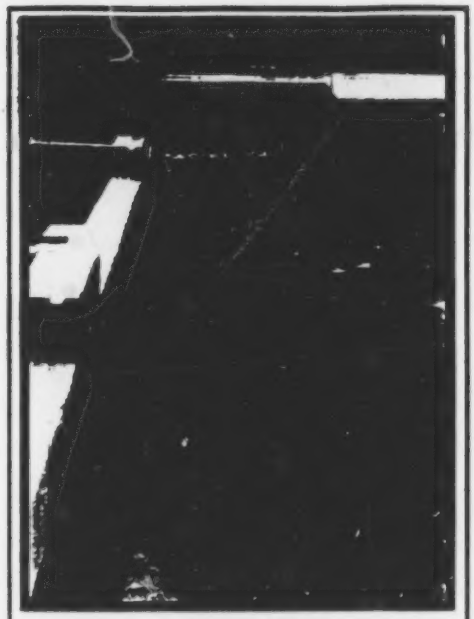

Figure 1-4
Building materials should not be piled too close to the edge of a trench. Note the material that has caved-in near this bundle of building material.

Based on personal opinion and past experience, many contractors decide there is no danger from cave-ins on smaller jobs. By allowing employees to work unprotected in trenches they not only endanger workers but risk prosecution and fines for violating regulations enforced by the Occupational Safety and Health Administration (OSHA).

Figure 1-3
A trench is created when the distance between a wall and the face of an excavation is less than 15 feet (measured at the bottom). Even if the trench is only 5 feet deep, a cave-in can kill or injure workers in the trench.

The OSHA Standards
Regulations concerning trenching and excavation operations are covered in the OSHA Federal Register Sections 1926.650-1926.652. These regulations spell out specific protection systems and their uses. All are based on a soil classification ranging from TYPE A which is stable material such as rock to TYPE C which is a sandy, gravelly material. A soil analysis to determine

which type of material the excavation will be performed in, must be conducted by a competent person (as defined in the section definitions).

Excavations 5 feet or greater in depth and narrower than 15 feet (measured at the bottom) must provide a protection system. In a site work situation, the 15 foot width is measured from the bottom of the excavation to the closest form work or other structure.
Protective systems can be as simple as sloping the excavation walls to an angle where the material will not slide or cave, to tight sheet shoring or other support structures. Further regulations specify that any excavation greater than twenty (20) feet in depth must have protective systems designed by a registered professional engineer.

Figure 1-6
Trench protection includes sloping or benching of the trench walls to prevent sliding or caving.

Many states that have their own OSHA program have adopted the federal laws. Copies of the federal regulations can be obtained from state regulatory groups. Remember, though, that OSHA laws give only minimum requirements for the protection of employees. Judgement must be used in interpreting the requirements.

Concrete contractors probably don't dig most of the trenches their people must work in. However, if the contractor allows his people to work unprotected in an excavation or trench, the law holds him responsible even if his workers did not dig the excavation. The person responsible is the one with employees exposed to danger. A prebid review of drawings and specifications can help contractors to foresee a problem and work out solutions before the actual work begins.

Figure 1-5
Water at the bottom of an excavation can cause unstable soil conditions and should warn workers that cave-ins are possible.

Recognizing Hazardous Trenching Conditions
OSHA regulations require contractors to provide safety training and education for all employees. Foremen and workers should be trained to watch for conditions that can cause trench failure and to recognize indicators of potential cave-ins such as tension cracks in soils near the top of an excavation.

Several conditions that can be direct causes of trench failure are listed below.

- Material or equipment too near the edge - Building materials or spoil piled at the edge of a trench can overload the soil and cause a cave-in. The piles of material may also hide tension cracks that would warn of an unstable slope condition. Spoil banks and stored materials should be no closer than 2 feet from a trench edge. Equipment shouldn't operate too close to the edge.

- Previously excavated areas - Trenches are particularly dangerous if they have been dug through or adjacent to backfilled areas. Disturbed soil, even if it is compacted, doesn't bind well to natural soil.

- Intersecting trenches - Digging utility line trenches that intersect a building excavation disturbs the soil and can cause a cave-in.

- Vibration caused by traffic or blasting - Sandy soils are especially sensitive to vibration. Truck traffic, moving equipment or blasting may

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trigger a trench failure.

- Wet soils - Clayey and silty soils lose strength when they get wet. Water in the bottom of a trench (figure 1-5) is a danger signal.

- Load from existing structures - If the bottom of a trench is lower than the footings of an adjacent structure, loads from the structure can cause a cave-in.

- Changes in the weather - Spring thaws, prolonged dry spells and rainy weather can all increase the likelihood of a trench failure. Thawing can reduce the load-bearing capability of some soils. Drying causes clay soils to crack. And wetting, as mentioned previously, reduces the strength of many soils.

Figure 1-7
Erosion control procedures may help stabilize trench walls during wet or rainy conditions.

Safety Pays

The cost of a trenching accident that kills or injures workers can't be measured in dollars only. But dollar costs alone are substantial. Workers' compensation costs resulting from an accident are only the beginning because insurance rates are directly tied to yearly compensation claims. In addition, a contractor loses the injured worker's production time and whatever time is required getting help for him. If the injured person can't work at full capacity after recovery, more production time will be lost, or there will be a cost for replacing him.

Trench safety measures are the law, and they make money sense, too. In addition, a construction worker has the right to the safest possible environment. Providing that safe environment is the management team's responsibility.

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Article 4: Worker Safety in Formwork Operations

Proper jobsite practices reduce injuries and accidents

by: Raymond A. Jurewicz
Manager, Equipment Development
Equipment Operations
The Ceco Corporation

Personal injury due to construction accidents inflicts pain and suffering on the hapless victim and costs the construction billions of dollars each year. Recognizing the dangers to workers in erecting and stripping formwork is a primary way of reducing this human and financial waste in concrete structures.

Major categories of accidents in forming and shoring activities are:

- Falling from one level to another
- Being hit by falling objects
- Improper lifting practices

Why Are Falls So Frequent?
Concrete formworkers often work at the upper reaches of a building where no structural members are available as anchorage for safety lines. They start with nothing in the air and work to make a solid membrane that will hold concrete. Until the last form is put into place or the last sheet of plywood is laid, there are openings in the deck. Perimeter protection or guardrails cannot be installed until something exists on which to attach the guardrails. The stripping of deck forms can leave openings in the floor through which an unsuspecting formworker may fall. And last, but not least, are inexperience and the eagerness of some formworkers to get a job done with the materials closest at hand.

Preventing Falls During Deck Form Erection
In a traditional deck forming operation, the first members raised are 4x6 stringers. Shores are attached at the ends and a tie board provides temporary support. Many formworkers feel that the easiest job in the work of raising stringers is to be on the stringers nailing the shores and the tie boards while the people below do the hard work. This requires that they walk a 4-inch beam located 10, 12, or 20 feet in the air. It may be easy, but it's an accident waiting to happen. The proper technique is to work from ladders or rolling scaffolds that rest on the finished floor.

The second step in conventional deck forming is placing the runners or ledgers-typically 4x4's or aluminum purlins. Walking 4x4 runners may be a little less dangerous than walking stringers, but stepping on a twisted 4x4 can cause a worker to lose balance and roll the 4x4. To eliminate this type of fall, keep plywood or a plank as close as practical to the point where 4x4's are being placed. Or in some cases the 4x4's can be distributed from below with powered lifting vehicles.

Changing the forming system is sometimes a practical way to reduce the hazards. Form table panels built at ground level can be flown into place, supported on scaffold-type shoring towers or trusses. The panels also may be rolled into place on support brackets mounted on columns or bearing walls. When these panels are set in place they provide a reasonably secure platform from which to start working.

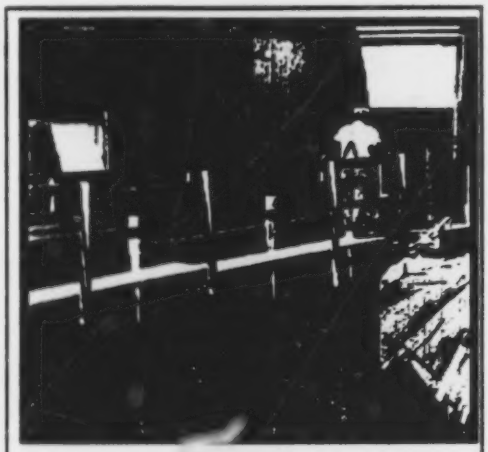

Figure 1-8
Working platform and guardrails attached to wall forms protect workers from falls at building perimeter during wall forming and placing operations.

Protection At The Building Perimeter
The perimeter of the building is a danger area when conventional post shoring is used. Here the fall may be off the side of the building to the ground many floors below. Perimeter panels sometimes solve this problem. These panels, designed to provide continuous walkways and guardrails, make the building perimeter secure as soon as they are flown into place. On jobs that use flying deck forms, similar perimeter protection can be readily installed on the flying form unit.

Holes and Openings

Elevator shafts and core walls present another problem. Guardrails are not too practical at the working levels of the deck because the wall-form workers must go beyond the guardrails to do their work. Also, guardrails can be easily knocked down or damaged during stripping operations, especially if traditional stick-built forming is being used. It is more practical to cover the openings. At the wall form level, a platform can be hung by cables just below the wall forms. This platform can be built to fit tightly into the opening without dragging on the walls as it is being lifted. Being suspended by cable, it does not interfere with the contraction or expansion of the wall forms. At the stripping level, a wedged platform can be constructed. Easily lifted from one level to another, it is wedged back into place at the new location.

Figure 1-9

Small openings covered with a single sheet of plywood can be more dangerous than large openings which must be covered with 4x4's and plywood. The reason: a natural tendency when picking up a sheet of plywood is to step forward and into the hole.

Other openings in the floor present different problems. It is probably safer to frame through openings at the formwork erection level and to cover openings at the stripping level, because guardrails at these levels also are susceptible to damage. Our experience indicates that small openings which can be covered with a single sheet of plywood are more dangerous than large openings that must be covered with 4x4's and plywood. The reason is that the natural tendency when picking up a sheet of plywood is to step forward and into the hole. Securing plywood to the concrete doesn't always work because the follow-up trades may remove the plywood to permit hoisting of materials or for other reasons and then fail to secure it again.

Special marked hole covers can be used, but this requires that they be available when needed and not be used for any other purpose. Covering the hole, but leaving part of it visible, will at least warn a worker that the hole is underneath. Probably the safest way to cover any openings through which a person might fall is by using cleated 4x4's in the opening and then covering it with plywood securely nailed.

Ladders

Ladders are thoroughly covered by the Occupational Safety and Health Administration (OSHA) regulations. One special problem with extension ladders, however, is worth mentioning. When an extension ladder is secured at the top and someone unwittingly moves the bottom of the ladder or pulls up on the top of the ladder to secure it, the latch mechanism can become undone. When the next worker goes to move the ladder and loosens the top, the ladder may collapse and cause injury. The latch mechanism should always be secured so that it cannot be unintentionally opened.

Safety Belts

Safety belts should be supplied and used when erecting high scaffolding or working on wall forms. Lanyards should be used whenever working outside guardrails or when attaching rigging to flying forms.

Figure 1-10

Workers wearing safety belts anchored to form panels can prevent falls during form stripping operations.

Form Stripping Hazards

An innocent act that can lead to a serious fall may occur during the stripping process. Sometimes when shoring is removed, the plywood still sticks to the concrete and can overhang the edge of the building or into an opening. An unsuspecting worker on the concrete floor above may step on this unsecured plywood and fall. The

stripping crew must be told of this danger and instructed to remove such plywood as soon as possible.

In some areas it is still common for the crane to snatch material off the side of a building. This requires a worker to lean out over an unguarded edge of the building to pull in the cables. If this technique is used, the worker doing the rigging should be secured with a lanyard. It is better to use an outrigger platform. Then the load can be wheeled outside the building line and the rigging can be done in a safer way.

Steel pan forms or domes are commonly removed from the ceiling by workers on an elevated platform.

Usually the platform is elevated less than 6 feet above the ground, therefore requiring no guardrails to meet OSHA standards. However, it is necessary to equip at least one edge of the stripping platform with a guardrail to prevent dangerous falls at the edge of the building.

Injuries Caused By Falling Objects
Being hit by falling objects is the second largest category of construction accidents. It's easy to see why falling objects can be a problem in formwork erection and stripping.

Material handling is 50% to 80% of formwork labor. Material is being put up, taken down, and moved horizontally. The areas to which material is moved are not completely decked over, nor is all the material immediately fastened to what is already in place. Tools, material, and debris can be knocked off easily or dropped from an uncompleted formwork deck. During stripping even the most experienced formworker can sometimes be hit by a falling object. Other tradespeople not aware of the dangers of form stripping should be kept out by a warning rope strung around the stripping area.

Precautions During Formwork Erection
All formwork members should be secured as they are put into place. Butted stringers should be nailed in a special head designed for this purpose. Shores should be secured at the stringers with a wire head or other means of fastening. An unsecured shore can fall as loads are placed on the deck or moved along the deck. A falling shore can injure an unsuspecting worker. Wooden crossbracing or other means of lateral support should be installed as soon as the first stringers are raised. Stringers being raised from a stabilized deck should be secured with a tie-off board. Lateral stability must be established before any loads are placed on the shoring.

Using fewer loose pieces reduces the likelihood of falling objects. Using perimeter panels, interior panels, column mounted shore panels, or truss panels wherever practical reduces significantly the number of loose pieces. When flying any panels from one level to another, remove all lose objects or see that they are secured to the panel. Debris and concrete chips should be removed from the panels before flying.

Objects Falling During Stripping and Reshoring
In stripping operations, controlled lowering with scissors-lift platforms reduces the danger from falling objects. A scissors-lift platform is especially useful at the perimeter of the building or near large openings that for some reason are not covered.

Reshores should be held in place with spring boards or spring clips. These devices allow the reshores to be snugged to the ceiling without putting undue load on the reshores, and they can accommodate movement in the building. Extra care is needed when placing reshores at the perimeter of the building. Perimeter reshores that are outside the guardrails or are exceptionally tall should be laced together with horizontal wood strips. If any perimeter reshore becomes loose, the lacing keeps it from falling off the building.

When pushing out large panels that completely frame under an opening, be sure to clean out the rebar, chairs, excess concrete, and other debris that may have accumulated in the opening. If the panel is not lowered so that this debris can clear the ceiling, the material will slide on top of the panel and shower an unsuspecting worker who is pushing out the panel.

Formwork material should never be left stuck to a ceiling. It may seem tight but a few temperature cycles and drying of adjacent areas can loosen stuck pieces and cause them to fall. Used dome pans and used steel forms, which usually require a considerable effort to break free, are generally considered safe to be left in the ceiling. However, new glass-fiber-reinforced forms, new wide-module steel forms, and joist forms with cover plates to create skip joist framing can and should be expected to fall by themselves. Special care should be used when working with this type of form.

Stacking of long slender materials, such as wooden shores, that could easily fall from the stack should be done carefully, especially at the perimeter of the building or near large openings. A stack placed parallel to the building edge or an opening edge greatly increases the possibility of a falling object accident. Stacking materials perpendicular to these edges will reduce the possibility of a piece falling off the stack and off the building. Banding a completed stack before moving the stack also is a good practice.

Improper Lifting

The third most significant cause of accidents is improper lifting. Improper lifting is an accident factor once again because of the large amounts of material that must be moved on formwork jobs. Another concern is that sometimes material moving may be done under less than ideal footing conditions. Unused rebar, loose concrete, and formwork debris are common in construction areas. Slipping or tripping while carrying even a light load can cause a strain.

The best way to avoid improper lifting accidents is to:

- Teach employees to lift properly
- Teach them when to get help in lifting or moving material

Good housekeeping is a must in reducing lifting accidents. In addition to preventing tripping or stumbling, it makes it easier for an employee to position himself properly to lift the load. Formwork systems also can be designed so that fewer pieces need to be moved manually. Many of the panelized systems previously mentioned fit into this category. Wheels can be a big help in reducing lifting strains. Putting material on carts and pushing it is more efficient and is less likely to cause accidents. It also requires that the areas on which the carts are used be kept clean. The controlled stripping techniques using scissors lifts also can reduce improper lifting. Removing material at a convenient working height is much less likely to cause strains than picking up everything from the floor.

Supervision and Experience Needed

Erecting and removing formwork exposes workers to many hazards. Good engineering and a good safety program are important. But competent jobsite supervision and experienced formworkers are the real keys to accident-free jobs.

Article 5: The Burning Facts of Cement

Cement, when it comes in contact with the skin, has a burning effect causing drying and cracking which in some individuals may lead to a serious case of secondary infection. It has two properties which produce an irritating action on the skin. One being that it is hygroscopic (capable of absorbing water) and the other is that it is alkaline which gives it a caustic effect.

The defense mechanisms of the skin can withstand the action of water and even fairly strong acid, but they are attacked by strong alkalis. Perspiration normally dilutes water-soluble irritants, but under certain conditions it may promote the action of irritants on the skin. Workers who perspire excessively are more likely to develop dermatitis (skin inflammation) from solid substances such as cement. There is always lime in the cement, and the more lime the more caustic effect it has on the skin.

Cement dust is ordinarily classified as a nuisance dust with a permissible exposure limit of 15mg per cubic meter under osha regulations.

Additives used in the cement are of little hygienic importance.

The essence of all prevention of industrial dermatitis is to prohibit skin contact with possible irritants, or if this is not possible, the earliest removal of the irritants from the skin. Prevention of contact is accomplished by using protective clothing and protective creams.

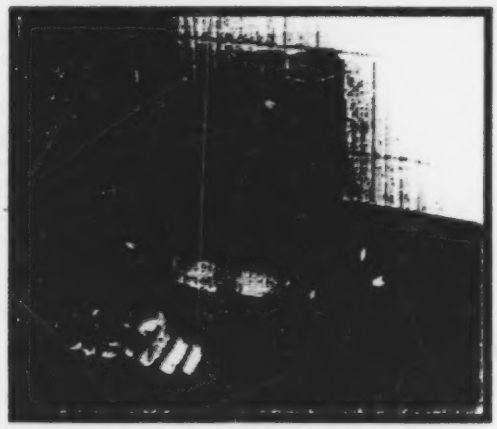

Figure 1-11
Personal protective equipment and clothing that should be used to prevent skin contact with wet and dry cement.

Men working at jobs such as operating a screed should wear protective gloves and adequate rubber boots. Care should be taken that the interior of the gloves and boots are kept clean. Severe cement burns have resulted when workmen have continued working in cement with a crack or a hole in their boot. If cement should get inside a boot or shoe, the footwear should be removed as soon as possible and the cement washed from the skin.

Excessive perspiration combined with friction also macerates the skin, lessening resistance to external irritants. The grains of sand or gravel used in the concrete mix also can be irritating, even though the skin is not broken or cracked in any area.

When the water is added to the cement a chemical reaction takes place changing the lime from calcium oxide to calcium hydroxide, producing heat in the reaction. Dry cement coming into contact with the hands absorbs moisture from the skin and causes the skin to become hard and dry. In some cases it causes the skin to thicken resulting in severe cracks which may bleed. These cracks are always a source of secondary infectior..

Cement not only affects the skin, but it also has a marked action on the fingernails, causing them to become dry and brittle. Persons who perspire freely are more likely to be affected by the dry cement. This is the reason that in some cases there is less action on the skin in the winter time than during the hot summer months.

Frequent locations of cement dermatitis in addition to hands and feet are the wrists, neck and waist. This is caused by cement on the clothing being rubbed against the skin by close fitting clothing. There have been many cases of cement dermatitis on the front of the body where the handle of a hand buggy was covered with wet cement.

Recommendations to eliminate contact with the skin of both wet and dry cement:

1. That boots, gloves and clothing impervious to moisture be used while working with wet concrete or cement.

2. That protective creams be used on the hands if gloves are not readily available.

3. That the interior of boots be washed after each use with soap and water, and thoroughly rinsed

with clean water.

4. That someone be placed in charge of the protective clothing, and he or they ascertain if the protective clothing shows any rips or tears which might allow the cement to come in contact with the wearer's body.

5. That where cement buggies are used, a rubber apron be supplied to prevent the buggy handle from rubbing cement into the skin.

Avoid Concrete Health Hazards

Precast concrete hazards

Dust

Concrete is a mixture of portland cement and gravel. It is often necessary to grind, drill and chip concrete, which causes a significant amount of dust. Control dust through wetting, mechanical exhaust ventilation and personal protective equipment or respirators.

Dermatitis

Working with wet concrete can cause cement dermatitis. Prevent this by wearing gloves, long sleeve shirts, proper boots and rubber aprons. Cement workers should wash regularly during the placement. Foremen must ensure adequate washing facilities are available and encourage workers to wash up.

Form oils

Form oils are used on wood forms to prevent concrete from adhering to them. Form oils are generally petroleum fuels and diesel oil sprayed on the forms. These pose a relatively low health risk. However, special form oils can contain isopropyl alcohol or other solvents which increase the health risk as well as the fire hazard.

The sprayer creates an oil mist which may be inhaled. Inhaling this mist over a period of time can cause respiratory irritation. Therefore, the use of respirators should be considered before each application.

Form oils generally are stored in 55-gallon drums and dispensed by gravity feed. Store the drums in a cool, dry place out of direct sunlight. Good ventilation is important since these liquids are combustible. Prohibit all ignition sources, which include cigarettes, around the containers.

The greatest concern with form oils is skin or eye contact. Most fuel oils are skin irritants. Avoid contact with form oils by wearing protective gear, gloves and safety glasses.

Toxic Fumes

Some precast construction requires a considerable amount of welding. Fumes generated from welding may contain iron oxide and other toxic metals. Use ventilation and respirators to combat this problem.

Hearing Loss

Many operations in precast work involve noise at high levels. These levels should not exceed the eight-hour TWA of 90 dBA. Engineering controls, hearing protecting and worker rotation can be used to avoid hearing damage.

Concrete Surface Preparations Hazards

Chemical Burns

Sandblasting is often used to clean or remove stains on concrete or mortar. Muriatic acid is sometimes used, also. This can cause chemical burns to the skin and eyes. Wear protective garments, gloves and face shields with safety glasses when using acids.

Use a plastic or rubber pail to mix muriatic acid with water. Water added to acid can cause a violent reaction. Always add the acid to the water. Never vice versa.

Breathing Hazards

Grinding and sandblasting concrete causes breathing hazards. Sandblasting sand contains almost pure silica. If inhaled, silica can cause silicosis, a progressive disease which decreases lung capacity and can cause increased susceptibility to tuberculosis. Appropriate respiratory equipment is a must when sandblasting.

Minimizing Health Hazards

There are several ways to control or minimize employee exposure to hazardous substances or conditions. These control methods can be used alone or in combination with others:

1. Substitute a less harmful material for one which is dangerous to health.

2. Alter a process to minimize worker exposure.

3. Isolate or enclose a work operation to reduce the number of workers exposed.

4. Wet method reduces the generation of dust.

5. Local exhaust at the point of generation of contamination.

6. General or dilution exhaust ventilation with clean air to provide a safe atmosphere.

7. Personal protective equipment such as special clothing, respirators, gloves, glasses, etc.

8. Good housekeeping and good personal hygiene.

9. Administrative controls such as reducing exposure time, rotating jobs, etc.

10. Training and education to supplement control methods and satisfy hazard communication regulations.

As with all industries, the ultimate job of safety comes down to each individual. Proper management is the key. If unsafe acts and conditions are allowed to exist, then they will exist. Hazardous work and materials must be constantly monitored to assure that each person performs their job properly and safely. Training and education are also very important. In order to determine hazardous conditions, an employee must know why the condition may be hazardous. Supervisors need to work like a coach to bring employees together to work as a team.

SECTION II: CONSTRUCTION MATH AND MEASUREMENTS

Page 22 - 23	Basic Arithmetic Using The Decimal System
Pages 24	Decimal/Inch Comparison Table
Page 25	Decimal/Inch Conversion Table
Page 26	Basic Comparison Exercise
Pages 27 - 28	Conversion Examples and Exercises
Pages 29	Standard Rules and Measurements (Engineer's Ruler)
Pages 30	Exercise 6 -Learning to Read the Folding Rule
Page 31	Squaring Principles
Page 32	Quantity Calculations - Regular Shapes
Page 33	Quantity Calculations - Irregular Shapes
Page 34	Area and Volume Formulas
Page 35	Worksheet 7 - Estimating Concrete Quantity

Trainee Section Objectives

1. To demonstrate competency in basic arithmetic using the decimal system.
2. To demonstrate competency with converting measurements from the U.S. Standard system to the Decimal system.
3. To demonstrate correct measuring techniques.
4. To demonstrate competency with squaring principles.
5. To demonstrate the ability to calculate concrete quantites for regular and irregular shapes.

Exercise #1

Add the following figures. Be sure that the decimal point is in the correct place.

1. 5.06 + 10.75 + 16.03 =
2. 10.95 + 0.06 + 9.17 =
3. 3.951 + 18.976 + 21.977 =
4. 0.678 + 1.766 + 28.115 + 9.002 =
5. 16.773 + 8.76 + 30.4 + 19.111 + 0.022 =

Subtract the following:

1. 5.02 - 0.01 =
2. 10.28 - 5.67 =
3. 106.29 - 0.66=
4. 130.5 - 1.55 =
5. 0.695 - 0.34 =

Multiply the following:

1. 5.0 x 0.6 =
2. .06 x .05 =
3. 1.3 x 2.51 =
4. 21.31 x 2.01 =
5. 32.105 x 3.006 =

Divide the following and place the decimal point in the proper place:

1. 500 ÷ 50. =
2. 50.9 ÷ 15. =
3. 56.7 ÷ 2.5 =
4. 622.5 ÷ 2.66 =
5. 1005.99 ÷ .067 =

Exercise #2

	Multiplication
1.	5x7 =
2.	3x10 =
3.	10x10 =
4.	14x13 =
5.	101x51 =
6.	1034x201 =
7.	.51x 21 =
8.	1.21x.09 =
9.	6.18x1.16 =
10.	600x1.01 =
11.	195.5x10 =
12.	64.555x.50 =

	Division
1.	15÷5 =
2.	200÷10 =
3.	1134÷54 =
4.	570÷114 =
5.	5826÷6 =
6.	932880÷845 =
7.	.25÷.5 =
8.	4.5÷1.5 =
9.	100.÷.25 =
10.	341.4÷2.7 =
11.	.369÷.80 =
12.	5494.4÷54.4 =

DECIMAL/INCH COMPARISON TABLE

U.S. CUSTOMARY FOOT		DECIMAL FOOT
1"		= .08'
2"		= .17'
3"	1/4 FOOT	= .25'
4"	1/3 FOOT	= .33'
5"		= .42'
6"	1/2 FOOT	= .50'
7"		= .58'
8"	2/3 FOOT	= .67'
9"	3/4 FOOT	= .75'
10"		= .83'
11"		= .92'
12"	1 WHOLE	= 1.00'
1'-1"		= 1.08'

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U.S. STANDARD TO DECIMAL SYSTEM CONVERSION TABLE

FEET AND INCHES		TENTHS AND HUNDREDTHS
1/8"	=	0.01'
1/4"	=	0.02'
3/8"	=	0.03'
1/2"	=	0.04'
5/8"	=	0.05'
3/4"	=	0.06'
7/8"	=	0.07'
1"	=	0.08'
2"	=	0.17'
3"	=	0.25'
4"	=	0.33'
5"	=	0.42'
6"	=	0.50'
7"	=	0.58'
8"	=	0.67'
9"	=	0.75'
10"	=	0.83'
11"	=	0.92'
12"	=	1.00'
1'-3"	=	1.25'
1'-4"	=	1.33'
1'-6"	=	1.50'
1'-9"	=	1.75'

The six basic conversion parts to remember are:

1/8"	=	0.01'
1"	=	0.08'
3"	=	0.25'
6"	=	0.50'
9"	=	0.75'
12" or 1 foot	=	1.00'

Exercise # 3

Use the converion table on page 25 to onvert the following U.S. Standard expressions to decimal expressions:

1. 1/8" =
2. 1" =
3. 5" =
4. 11" =
5. 7/8" =
6. 8" =
7. 1/2" =
8. 3" =
9. 3/8" =
10. 9" =
11. 6" =
12. 3/4" =
13. 12" =
14. 2" =
15. 1/4" =
16. 7" =
17. 10" =
18. 5/8" =
19. 4" =
20. 7/8"=

70

CONVERTING COMBINATION FEET, INCHES, AND FRACTIONS TO TENTHS AND HUNDREDTHS

Examples: Change the inches to a decimal of a foot and the fraction to decimal of a foot, then add the two together.

A. **18 3/8" =?**

18"	=	1.50'
3/8"	= +	.03'
		1.53'

B. **11 5/8" = ?**

11"	=	.92'
5/8"	= +	.05'
		.97'

C. **2 3/4" = ?**

2"	=	.17'
3/4"	= +	.06'
		.23'

Exercise 4: Convert the following to feet, tenths and hundredths.

a.	2 1/2" =	b.	5 7/8" =	c.	7 3/8" =
d.	8 3/4" =	e.	3 1/2" =	f.	33 3/4" =
f.	27 1/4" =	g.	75 1/2" =	h.	4 1/4" =
i.	3 5/8" =	j.	6 3/4" =	k.	9 1/2" =
l.	8 3/4" =	m.	7 1/4" =	n.	21 1/2" =
o.	75 1/2" =	p.	2 7/8" =	q.	5 1/8" =
r.	6 1/4" =	s.	9 3/8" =	t.	1 1/4" =
u.	37 1/8" =	v.	10 3/4" =	w.	77 1/2 =

CONVERTING FEET, TENTHS, AND HUNDREDTHS TO FEET, INCHES AND FRACTIONS

Examples: Subtract the closest whole inch increment from the expression and convert the remainder to eighths (reduce to lowest terms if needed).

A.

4.28'	= ?	
-4.25	=	4' - 3"
0.03	= 3/8 =	+ 3/8
		4' - 3 3/8"

B.

0.89'	= ?	
-0.83	=	0' - 10"
0.06	= 6/8 =	+ 3/4
		0' - 10 3/4"

C.

8.37'	= ?	
-8.33'	=	8' - 4"
0.04	= 4/8" =	+ 1/2"
		8' - 4 1/2"

Worksheet 5:

Convert these to feet, inches and fractions:

a.	1.59 =	b.	6.87 =	c.	9.36 =
d.	.95 =	e.	.22 =	f.	3.45 =
g.	1.63 =	h.	10.73 =	i.	1.14 =
j.	12.06 =	k.	11.91 =	l.	4.41 =
m.	9.69 =	n.	1.24 =	o.	1.71 =

STANDARD RULES AND MEASUREMENTS

A foot on the U.S. CUSTOMARY SIX FOOT RULE is composed of twelve basic parts called inches. Each inch is divided into fractions that split the inch in half (1/2") then into quarters (1/4") then into eighths (1/8") and finally into sixteenths (1/16").

A foot on the ENGINEER'S SIX FOOT RULE is composed of ten basic parts called tenths. Each tenth is further divided into 10 ten smaller portions called hundredths. A foot has 100 hundredths (10 tenths times 10 hundredths).

Think of a dollar, it is made up of one hundred cents or pennies. The ENGINEER'S RULE with a foot broken down into one hundred equal parts can easily be compared to a one dollar bill in our money system. The ENGINEER'S RULE has one hundred hundredths to the foot. Using this frame of reference, the ENGINEER'S RULE is easily learned.

Look at the U.S. Customary side of the rule, which you have some familiarity with. Notice that the inches are denoted by large black numerals, and starting with the one foot mark the feet are designated by large red numerals and a large letter "F", "2F" equals the two foot mark.

Between feet, starting with the one foot mark, small red numerals precede each inch mark in that particular foot, so one can find a reading of 2' 10".

Look at the Engineer's side of the rule. You will notice that the tenths are denoted by large black numerals and starting with the one foot mark the feet are designated by large red numerals, and a large letter "F", "2F" equals the two foot mark.

Between feet, starting with the one foot mark, small red numerals precede each tenth mark in that particular foot, so one can find a reading of 2.30' (two and three tenths or two and 30 hundredths foot).

It is easy to change inches and parts of inches to tenths and hundredths or vice versa. Using the ENGINEER'S RULE, you hold your reading on one side and turn the rule over and without any mathematical trouble the change is made.

For example: one foot six inches (1'6") on the CARPENTER'S side equals one foot and five tenths (1.50') on the ENGINEER'S RULE side.

Now turn the rule over to the ENGINEER'S side.

The first thing you see is the two bold red lines running parallel the length of the rule. These lines help you to prevent error and mix ups by designating this side of the rule as the ENGINEER'S RULE.

CARE OF THE RULE:

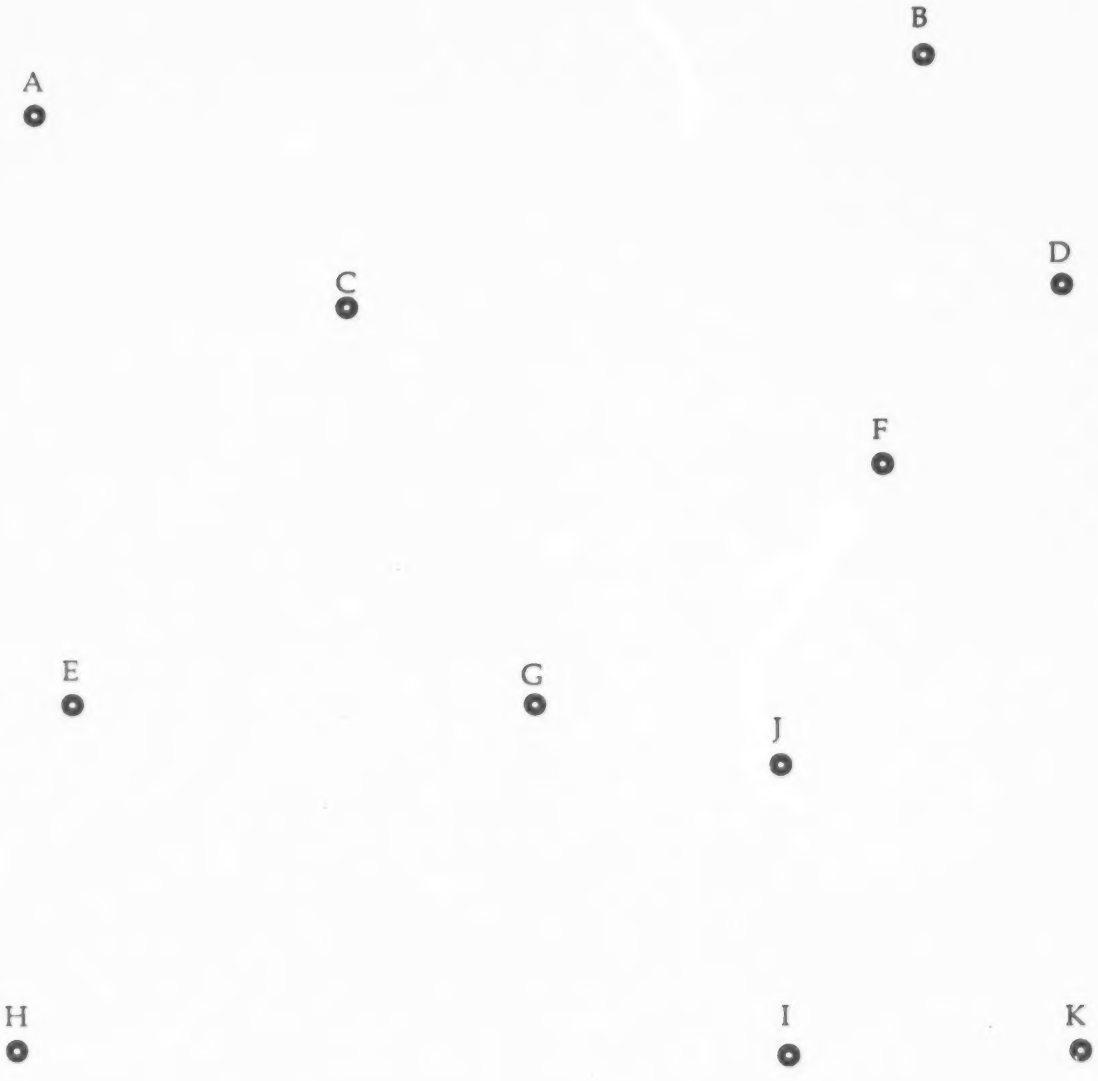
Take out a six foot ENGINEER'S RULE, unfold it carefully, six inches by six inches. Take care of the rule, fold it after each use. When folding after use, back it on itself, six inches by six inches. Keep it clean and take it out of your pocket before sitting down in a truck or car.

Rules to remember when reading an ENGINEER'S RULE:

1. First locate feet.
2. Find tenths.
3. Count hundredths. Any reading ending in zero is either tenths of feet (.50'), feet (4.00'), or feet and tenths (4.80'). Any reading ending in a numeral has to be read as hundredths of one foot (0.79') or as feet and hundredths (3.79').

Exercise #6

STANDARD RULE				ENGINEER'S RULE			
A-B	_____	F-G	_____	A-B	_____	I-J	_____
B-C	_____	G-H	_____	B-C	_____	G-H	_____
C-D	_____	H-I	_____	C-D	_____	H-I	_____
D-E	_____	I-J	_____	D-E	_____	I-J	_____
E-F	_____	J-K	_____	E-F	_____	J-K	_____



Squaring Principles

Example A: The illustration below depicts a square 15 foot by 15 foot. The formula shows that to calculate a diagonal you can multiply a side length by 1.414.

Formula: Diagonal = side length x 1.414

Example: Square is 15'x15'
diagonal = 15'x1.414
diagonal = 21.21'

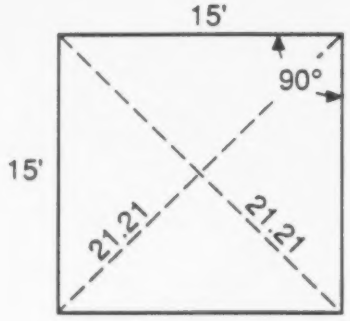


Figure 2-1

Exercise A: Using the formula above find the length of the diagonal of the following squares:

1. 20 ' x 20'
2. 80' x 80'
3. 42' x 42'
4. 75.45' x 75.45'

Example B: The illustration below depicts a rectangle 40 foot by 20 foot. The formula shows that you can add the squares of each side together and the square root of that sum will be the length of a diagonal.

Formula: Diagonal = $a^2 + b^2 + c^2$

Where: a = width of the rectangle
b = length of the rectangle
c = length of the diagonal

Example: Rectangle is 20'x40'

diagonal = $\sqrt{(20' \times 20') + (40' \times 40')}$
diagonal = $\sqrt{(400 + 1600)}$
diagonal = $\sqrt{2000}$
diagonal = 44.72'

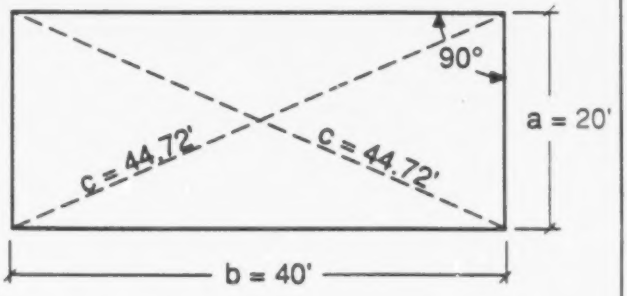


Figure 2-2

Exercise B: Using the formula above find the length of the diagonal of the following rectangles:

1. 24' x 30'
2. 36' x 72'
3. 18' x 65'
4. 25.17' x 38.42'

Method for Estimating Concrete Quantities - Regular Shapes

The initial step taken by every concrete user is the preparation of a clear and accurate concrete estimate. The main purpose of the estimate is an accurate description of required concrete quantities, whether the job is small or large, or the estimate is brief or detailed. This estimate enables the builder to predict his material requirements and is useful in determining the time it will take to place the concrete and is helpful in scheduling equipment for placement. The first step of an estimate is to isolate all concrete portions with an identical cross section, or all portions with the same width and thickness. Next, lengths of all concrete portions with the same cross section are totalled. The total length is multiplied by the cross sectional area to arrive at the volume. All dimensions used must be in feet, therefore volume will be expressed in cubic feet.

Example: A structure is to be built which has a plain footing wall with a uniform width of 1 ft. 4 in., and a depth of 8 ft. 6 in. The lengths of the footings are: 10 ft., 16 ft., 18 ft., and 12 ft.. To determine the volume of the footing wall:

a. Add all the lengths:
   10'+16'+18'+12'= 56 ft.
b. Convert the cross section dimensions from feet and inches to feet and decimals:
   1'-4"=1.33' and 8'-6"= 8.5'
c. Calculate the volume:
   56'x1.33'x8.5' = 633.08 cu. ft.

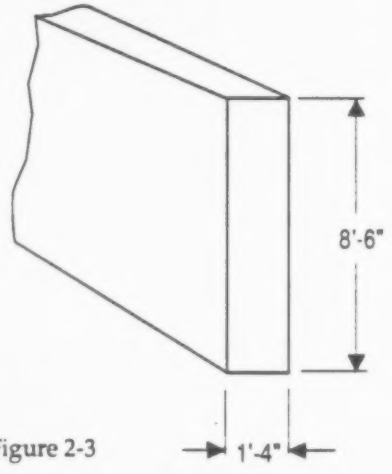


Figure 2-3

Concrete is always ordered in cubic yard quantities. One cubic yard is equal to 27 cubic feet. After calculating the volume of a project in cubic feet, divide the number of cubic feet by 27 to find cubic yards. In the example for Figure 2-3 the cubic yardage in the footing wall is:

633.08 ÷ 27 = 23.44 cubic yards

Items such as block-outs for door and window openings must be carefully checked to be sure that the volume occupied by these openings is not shown on the estimate as being occupied by concrete. These volumes are known as negative quantities and must be subtracted from the total concrete estimate.

In calculating the volume of concrete in a structure with corners, care must be taken by the estimator to insure that the corner volume is not counted twice. One method of preventing this error is to show the corner deduction in one portion of the calculation.

Example: Calculate the volume of concrete needed for a rectangular walled structure 8 feet high and 1 foot thick, with sides 28 feet wide and 40 feet long.

Calculations: **2 sides @ 28' = 56'**
2 sides @ 40' - 4' = 76'

Find the volume by using the following process:

(56'+76') x 1' x 8' =	**1056 cubic feet**
1056 cubic feet ÷ 27 =	**39.11 cubic yards**

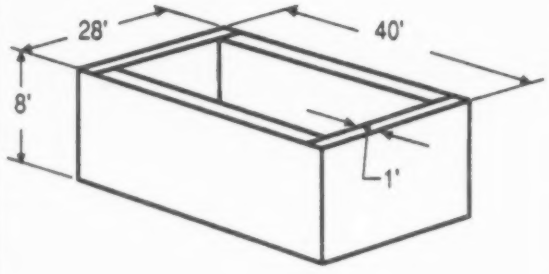


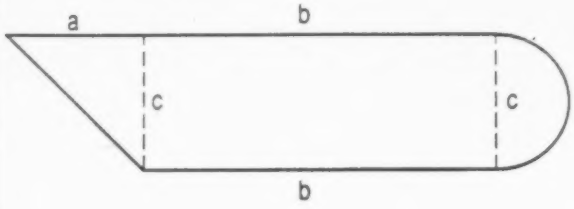
Figure 2-4

Method for Estimating Concrete Quantities - Irregular Shapes

When an area has irregular shapes it is easiest to divide the area into a group of regular shapes.

Example: Calculate volume for irregular shaped slab in Figure 2-5 if slab is 6" thick and length a=10', b=15' and c=8'.

Triangular area ac = 10'x8'÷ 2 = 40.00 sq. ft
Rectangular area bc = 15'x8' = 120.00 sq. ft
Semicircular area c = π(4x4)÷ 2 = 25.13 sq. ft.
(π = 3.1416)
(area of a circle = πR2)



Calculate the total area shown above and then add:

Triangular area ac = 40.00 sq. ft.
Rectangular area bc = 120.00 sq. ft.
Semicircular area c = 25.13 sq. ft.
Total = 185.13 sq. ft.

Calculate the volume in cubic feet by:

185.13 x .5 = 92.57 cu. ft.

Calculate the volume in cubic yards by:

92.57 cu. ft. ÷ by 27 = 3.43 cu. yd.

Figure 2-5

The basis for estimating concrete quantities is the same in simple or complex structures. In complicated structures and in areas of non-uniform thickness or shape the structure is divided into small, uniform shapes which are calculated and then totalled to produce an accurate concrete quantity estimate. The key to an accurate concrete estimate is to be certain that each volume is correctly calculated before moving on to the next item.

Another example of a common irregular shape is a standard curb and gutter.

To calculate concrete volumes for curbs, make the curb and gutter section into a regular shape by adding the height of the curb onto the length as is shown in Figures 2-6 and 2-7.

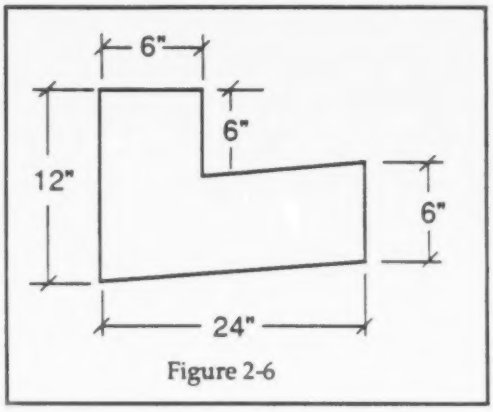


Figure 2-6

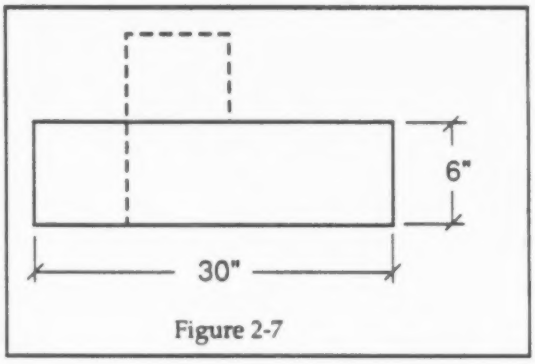


Figure 2-7

To calculate the concrete quantity for the standard curb and gutter section shown:

.5' x 2.5' x Length ÷ 27 = Cubic Yards

Area and Volume Formula

To Calculate Areas of:

a.	Square or rectangle	Area = length x width
b.	Triangle	Area = 1/2 base x height
c.	Circle	Area = π x radius2

To Calculate Perimeters or Circumferences of:

a.	Rectangle	Perimeter = (2 x length) + (2 x width)
b.	Square	Perimeter = 4 x width
c.	Circle	Circumference = π x diameter

To Calculate Volumes of:

a.	Rectangular box (cube)	Volume = length x width x height
b.	Cylinder	Volume = π x radius2 x length
c.	Sphere	Volume = 4/3 x π x radius3
d.	Wedge	Volume = $\frac{\text{base x height x depth}}{2}$

Exercise # 7

Calculate the quantity of concrete required to pour the following structures. Express your answers in Cubic Yards.

Sidewalk:

1. 4" x 4' x 240'
2. 5" x 5' x 820'

Slabs:

3. 5" x 24' x 48'
4. 6" x 36' x 54'

Walls:

5. 8" x 8' x 140'
6. 12" x 10' x 190'

Footings:

7. 10" x 16" x 140'
8. 12" x 2" x 280'

Round columns:

9. 3' diameter x 24' high
10. 5' diameter x 32' high

SECTION III: PROJECT PLANNING

Page 37 - Scale drawing of hands-on training area

Page 38 Project plan outline

Pages 39 - 40 Article 6: *Planning is the Key to Building More Efficiently*

Pages 41 - 44 Article 7: *Coordinating Formwork Plans With Overall Project Planning*

Pages 45 - 51 Article 8: *Overall Planning*

Trainee Section Objectives

1. To become aware of the importance of proper project planning.
2. To demonstrate this awareness in future field exercises and construction projects.

Shop Drawing of Project Area

Drawing to contain all existing structures in solid lines. Proposed projects drawn in using dashed lines.

Project Plan Outline

Project Plan:

1. Site inspection
   a. Take measurements
   b. Make a rough sketch of area
   c. Make notes on site preparation, etc.
2. Shop drawings
   a. Review scale drawing of area
   b. Add class projects to drawing
   c. Add all needed dimensions to drawing
3. Construction plan
   a. Spoil storage
   b. Size and type of equipment
   c. Material storage
   d. Reference point location
   e. Size and type of compaction equipment
   f. Type of forming system
   g. Placing concrete-access for forms- equipment needed
   h. Size of crew
   i. Form stripping and storage

Article 6: Planning is the key to building more efficiently

by: Joseph R. Proctor, Jr.
Construction Consultant
Lake Oswego, Oregon

Shop drawings aren't provided on time. Construction materials arrive out of sequence or late. Cranes on the job have inadequate capacity or reach. Precast concrete arrives at the jobsite, but correct chokers and slings needed for unloading it aren't available. All these problems have the same effect-a slip in construction efficiency and productivity. But concentrating on the effect gives too little attention to the cause of the problems-not enough emphasis on planning.

Without good planning, efficiency in construction can't be achieved. One reason for this is a constantly changing work force. Except for contractors who work only in their own area, most general contractors acquire a new work force on each project. Only project managers and key superintendents move from job to job. Providing these key people with a well-thought-out plan will help them get the new supervisors, including foremen, up to speed quickly.

Develop plans in detail

Planning requires more than just feeding scheduling data into a computer program Good old-fashioned hands-on planning requires a close look at each construction operation. At the start of every project-preferably when the estimate or proposal is made-develop a detailed, realistic plan for building the project. Don't use the backward approach of unit-pricing the quantities of work, then after the contract award, figuring out how to build the job. Having a construction plan early in the game doesn't rule out making changes once the project starts. But it does help you compare and evaluate construction options. There's more to a plan than just selecting major equipment and construction methods. The plan should cover activities such as:

- Sequence of construction of various parts of the project
- Temporary facilities such as shoring, cofferdams, and trestles
- Access for delivery of materials and positioning of erection equipment
- Provisions for and distribution of electricity, water, fuel, and compressed air
- Communications, such as telephones, radios, or pager
- How the materials are manufactured: The aggregate plant, concrete mixing or batching plant, prefabrication or preassembly of components, and shops for making ducts, piping, weldments, and formwork for concrete
- Offices, shops, storage areas, and warehouses
- Movement of personnel and materials
- Removal of debris
- Cold or hot weather protection provisions

Each activity can affect the other, and each needs to be considered in the written plan. For instance, a man-lift on the outside of a high-rise can delay the installation of exterior panels or facing. Locating the man-lift to reduce this problem takes planning. Preparing a plan for erecting precast concrete should include when to acquire chokers, slings, blocking, and shims, and it should describe how to install inserts for attaching the precast elements to the structure.

Make an outline of the plan on paper with as much written description as possible to reduce misinterpretation. Then send the preliminary draft to the supervisory team for its critique and suggestions.

Supervisors need to be knowledgeable

The size and complexity of a project determines how detailed a plan should be. But most important in getting such a plan off the ground is making sure it's understood by superintendents and the foreman. Without good leadership the job won't be done well. Construction supervisors (including superintendents, onsite project managers, and general foremen) should have the following qualities:

Job knowledge - knowledge of the job requires endless hours studying the plans and specifications. The 8-hour day the craftsman works is not for the dedicated and effective superintendent. He or she can't gain a thorough understanding of the project during the working day when the crews need organizing and managing.

Industry knowledge - It's surprising how uninformed many construction supervisors are of

new methods and materials in use in the industry. They must read various trade publications, visit other projects (preferably of the competition), and exchange ideas with other construction people.

Job Contact and Communication - Construction has a changing mix of work activities and requires close and perceptive supervision. This cannot be done from a desk in front of a computer. Supervisors need to verify the quality of the work, assure that workers adhere to the schedule and construction plan, and resolve problems. Even the project manager needs to be walking the job once or twice a day. The conductor of an orchestra doesn't just start the music with a few baton strokes and then take a seat in the first row and listen to the music.

How to control subcontractors and suppliers
To keep the job on schedule, the subcontractors and suppliers must know what is expected of them, and they must be tied to the schedule by the terms of their contracts or purchase orders.

Manufacturers prefer to run out orders and ship them immediately. They also like to manufacture projects of one size all together before producing another size. Contractors must determine the schedule and sequence of shipments and obtain commitment from the supplier to adhere to this plan. If the supplier requires that you accept a full shipment at once, you must be prepared to provide storage and handling or compel the supplier to store the material and deliver to the job as needed.

Subcontractors also have preferences as to how they wish to perform their work. These preferences may not be consistent with the project's plan though. If, for instance, parts of the subcontracted work have to be delayed because of access problems, this should be explained before awarding the subcontract and established as one of the conditions.

It's best for the detailed construction plan to be ready at the time subcontracts are negotiated so that all factors can be considered. Subcontractors also should be informed at this time as to what facilities will be provided or made available to them. You may need to provide for storage, potable water, heat, weather protection, power, debris removal, and material handling equipment.

Prejob and weekly meetings keep job on track
The best way to let everyone know what's expected is to hold a prejob meeting with subs, suppliers, and supervisory staff. This lets each person discuss his or her needs and concerns. Before committing to an expensive form, for instance, a concrete forming sub needs to know if a plumber or electrical sub must penetrate the forms.

Holding meetings once a week during the job is also a good idea. That way any needed changes to the plan can be incorporated easily because everyone will be aware of them. All subs active on the project or due to start shortly should attend the meetings. On an efficiently run job, the supervisory staff controls activities of the subs as though they are part of the general contracting team.

Although no amount of study or planning covers everything, the planning effort is never wasted. Nothing contributes more to a cost-effective job than the onsite presence of knowledgeable and prepared supervisors. And nothing contributes more to supervisor preparation than a detailed, written plan of how the project should be built.

Article 7: Coordinating formwork plans with overall project planning

by Joseph R, Proctor, Jr.
Construction Consultant
Lake Oswego, Oregon

So much emphasis has been placed on formwork as a major part of the cost of a concrete structure that at times we may put too much effort into planning and constructing the formwork systems without adequately considering the best interests of the overall project. The concrete forming plan and selection of form handling equipment can have serious consequences for other trades and operations, including both subcontractors and the general contractor.

Formwork planning typically concentrates on speed of erection and removal which reduces cost through form reuse and minimization of manpower requirements. Fast formwork erection and recycling tends to accelerate completion of the structure, thus allowing more time for follow-up operations such as mechanical and electrical installations and architectural finishes.

Figure 3-1
Equipment placement is essential when planning a construction site.

Of course reducing formwork cost is highly desirable, but not if it causes too large an increase in the cost of other operations. Therefore all features of a proposed formwork system and their effect on other aspects of the work must be carefully anlyzed, and cost comparisons must be made of the various options. In the discussion that follows a typical high-rise building serves as an example, although many of the points apply equally well to other concrete structures.

Figure 3-2
Material must be stored close enough to be easily available but not in an area where it must be moved to get to other material.

Sequence of operations

A project plan begins with determination of the overall duration of work, usually established by the construction contract. In deciding how much time is to be allocated to the structural frame we must consider the electrical, mechanical, architectural, and other miscellaneous disciplines and a multitude of project details. Allowance must be made for variables such as start-up operations or life safety testing, which can take an inordinate amount of time.

Also, we must consider how closely these operations can follow completion of various parts of concrete placement. If the building will be closed in with precast concrete panels or materials other than concrete, we must decide whether to do this closely following concrete operations floor by floor or wait for availability of cranes or other hoisting equipment after the building is topped out. If the forming system calls for several floors of forms and shores to remain in place below the newly cast floors, their presence can prevent interior work from following too closely.

Formwork system selection

Factors influencing the selection of a formwork system can be summarized as follows:

1. Cost of materials used to build the forms

2. Labor or manufacturing costs to build the forms
3. Design for simplicity of erection and stripping
4. Effect on architectural finish or detail
5. Access for concrete placing and for cleanout before placing
6. Safe access for workers including scaffolds, railings, etc.
7. Necessary camber and deflection control
8. Form handling and hoisting equipment
9. Shoring off subgrade or concrete slab on grade

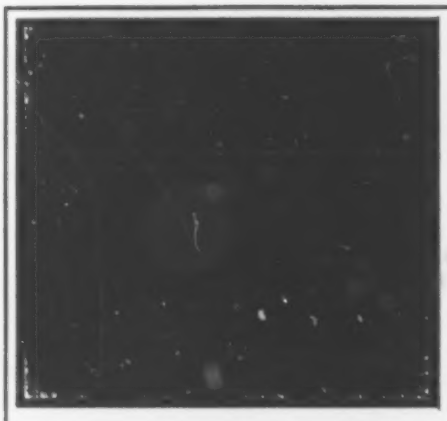


Figure 3-3
Time and sequence of the work of subcontractors must be phased into the formwork schedule. The conduits, blockouts, and rebar cannot be put down until the deck form is in place.

Architectural finishes
The first four factors listed should have little effect on operations other than the architectural finish. Systems based on multiple use of forms require better-quality materials to assure that the forms hold up over their full term of use. This becomes particularly important where the exposed concrete surface quality is critical. Painted or textured ceilings depend heavily on the quality of the form surface and its ability to withstand many uses. Architectural finish of walls, columns, and beam sides may require careful fabrication of form surfaces, sealing of joints and tie holes to prevent grout loss, and other measures to assure unblemished surfaces and accuracy of detail.

Before final selection of a forming system the job must be studied in detail to determine whether or not there are form penetrations needed which could affect the use of expensive material for contact surfaces and limit form stripping options. Look for such penetrations as masonry anchors, plumbing fixtures, piping, conduit, or embedded items requiring depressions in a floor slab. If a form is likely to be butchered to accommodate these needed items, it may make more sense to use cheaper material and replace or resurface it from time to time.

Access and safety
Items 5 and 6 relate to costs necessary to assure ease and safety for workers cleaning out forms and placing concrete. These expenses pay for themselves in the economies they bring about in those operations. Access requirements of other trades-such as rebar placers and post-tensioning crews-also should be considered in developing the forming system.

Deflection control
Where appearance of exposed surfaces is critical, forms are designed to limit deflection as well as to carry loads safely. This is particularly important for walls and columns where the rate of placement of concrete is apt to be rapid.

Suspended slabs, although not affected by the rate of placing concrete, have their own deflection problems. Sometimes the structural designer specifies camber to compensate for normal dead load deflections that occurs when the slab starts to carry its own weight. In addition to this the form designer locates and spaces shores and stringers to limit deflection during construction; if the design is not carefully thought out, it may be difficult if not impossible to incorporate the camber specified by the structural designer. Flying forms, which have a long span between supports must be designed stiff enough to eliminate deflection since they are not readily cambered by adjusting shores.

Requirements of other disciplines or trades must be considered in designing forms for critical areas such as elevator shafts, slab edges, and beams where prefabricated work or special architectural finishes are to be installed. Normal tolerances for concrete work may sometimes be unacceptable for the other trades.

In post-tensioned work, allowance may have to be made for the shortening of the slab during stressing. This can present problems for positioning exterior panels or for layout of interior work. Where a closure strip is required to join two post-tensioned slabs, special shoring of the cantilevered slabs is needed to control their deflection.

Hoisting equipment
Selection of form handling equipment (Item 8 above) interfaces with the process of selecting hoisting equipment for the project. We must consider other trades and operations at the same time we review the hoisting equipment needed for the proposed forming system.

Early in the planning process all operations requiring hoisting equipment must be listed and quantified in terms of hoisting time. The size and frequency of lifts must be studied to decide what type, capacity, reach, and number of units may be needed. Measures which can be taken to reduce hoisting requirements include the following:

- Flying forms in large ganged panels. This can reduce the number of picks required for form materials, but large wall panels may need placing pockets to minimize dropping concrete or avoid heavy rebar congestion.
- Self-raising wall and column forms
- Use of form material which can be handled by hand or transported vertically with hoisting towers or light-duty equipment
- Preassembly of rebar cages for columns or beams; sometimes also feasible for walls and slabs
- Use of concrete pumps and placing booms instead of placing by crane and bucket
- Having a second shift to perform part of the critical hoisting

Timing of hoisting needs also must be considered. If we plan to use the same crane for placing concrete and erecting exterior building panels, the latter would have to await completion of the concrete frame, even though closing in the building as it goes up would be preferable.

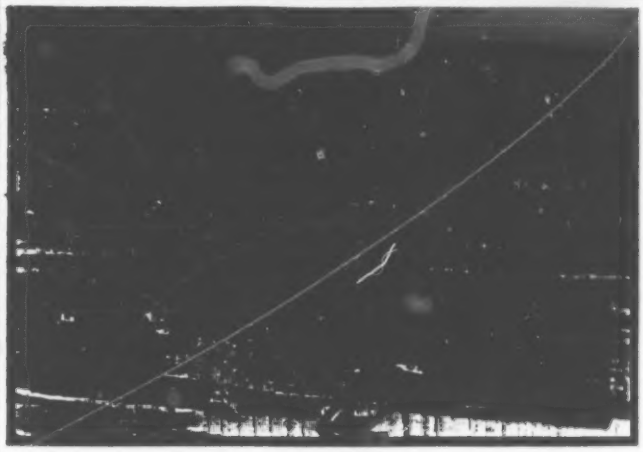


Figure 3-4
Pre assembled rebar mats for walls and slabs speed up site operations. Planning is needed for scheduling hoisting equipment needed for all construction operations.

The need to install structural steel or mechanical equipment on top of the building after the frame is completed may influence equipment selection. Debris removal also may be a factor. Material or personnel hoisting towers may be used, but in many cases debris handling chutes reduce the demands for hoisting time.

Hoisting equipment location
Where we put cranes and hoists is just as important as which ones we choose. Where flying forms are to be used, the crane selected to move them must have capacity and reach to handle their size and weight and must be positioned so that it does not obstruct their removal from the building.

When placing booms or even tower cranes are positioned within the building, they must be located carefully to minimize the effect on the structure of temporary openings in the slab as well as their potential for delaying other operations following concrete work.

Putting material or personnel hoists next to the building delays installation of exterior facing of the building in these areas. Expediting operations that lead to early construction use of permanent elevators help in obtaining earlier removal of the hoists and completing the closing in of the building.

Shoring off subgrade or slab?
Item 9 highlights the need for an early decision before starting to form the first suspended floor slab.

Shoring from a slab on grade costs less in both material and labor than placing shoring on mudsills, and it is easier to maintain a precise grade under load.

To get off to an early start on forming and shoring, careful review of the plans, particularly electrical and mechanical, should be made to determine how much underground work must be done before placing the slab on grade. It cannot be done quickly, then starting the suspended slab construction on shoring supported on mudsills may be necessary. If this occurs, we also must decide how to meet the project's need for temporary power and water where distribution lines for these must be located under the first or basement floor slabs.

Relationship with subcontractors

Although the general contractor is responsible for successful completion of a project, in most construction he or she accomplishes much of the work through subcontractors. In any well-thought-out plan their needs and obligations must be given full consideration. This process should begin in the early discussions at the time of pricing or bidding the work, and certainly before agreeing on subcontract items.

These are some of the subcontractors' concerns that may affect selection of the formwork system:

- Definition of responsibility for basic line and grade layout
- Access to the forms for installation or performance of their work
- Space required for storage of materials being installed
- Needs for penetrations through forms
- Time needed for installation of work in specific pours
- Construction joint location; potential conflict with the subcontractor's work
- Hoisting: type, capacity, reach, duration, and frequency or number of picks
- Means for removing debris
- Architectural concrete surface requirements that might limit the type of fasteners the subcontractor uses in attaching work to the forms

A thorough and detailed review with the subcontractors of all aspects of a project plan and schedule, including details and sequence of formwork operations, is essential to completion of a project and minimization of conflicts with subcontractors or owners.

For a successful plan with a minimum of conflicts, no one operation can be planned without consideration of its effects on all other project features.

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Article 8: OVER-ALL PLANNING

Formwork is the stock in trade of the concrete contractor, and how he handles it can make or break the profitability of a concrete job. To achieve minimum cost in the construction and use of formwork, it must be treated as an integral part of the total job plan. The over-all construction sequence must be planned to use formwork in the most efficient manner and to permit the optimum investment in formwork to meet schedule requirements. Availability and cost of local labor and materials should also be considered in developing the plan.

For his own protection, a contractor should plan formwork and job sequence at the time of making a bid. Failure to study a job thoroughly enough to arrive at the most efficient plan may cause loss of the contract. Even worse, to receive a contract in reply to a bid based on a superficial analysis, and then to find that some aspect of the assumed plan is impractical so that the actual costs will be much higher than anticipated, can be disastrous financially. Advance planning will also help to insure the unqualified safety of personnel engaged in formwork and concrete placement and the integrity of the finished structure.

Development of a Basic System

The formwork plan must be adapted to the layout of the concrete structure and to a practical construction sequence. Each job will have some feature or combination of features that will tend to establish, more or less automatically, the basis of an efficient formwork plan. These features may exist in the design of the building, in site conditions, or in other factors. The most efficient system can be determined initially through analysis of placing schedules and stripping time requirements, but practical limitations will be imposed by accessibility and site conditions and by the capacity of equipment available to handle form sections and materials. Among the other major factors to be considered are:

1. Capacity of mixing and placing equipment
2. Construction joints (if specified) which limit size of lifts or placement units
3. Form construction details and facilities for form building
4. Reuse of forms as affected by stripping time and other requirements
5. Relative merits of job-built, shop-built, and ready-made forms
6. Type of surface on which formwork is supported (concrete, sand, clay, wet, frozen, etc.)

Compare Alternate Methods

Different basic objectives, or alternative plans and methods for achieving the same objective, should be examined in detail so that over-all costs can be compared. Initial form construction costs, savings through reuse, and costs of setting and stripping are compared to arrive at the lowest-cost formwork plan. In addition, for each plan a comparison should be made of the estimated number and types of rigs, hoists, and other equipment required, and the efficiency with which concreting crews, reinforcing crews, and others will fit into the schedule. In determining total cost for each plan, allowance must be made for preparation and familiarization time at the beginning of the project and finishing up "loose ends" at its conclusion.

Examine Form Plan in Relation to Total Job

After selecting the most efficient plan, the contractor should review his formwork plan along with the specifications to make sure there are no special requirements or conflicts that would make some detail of his plan or intended form design impractical. He also should review the plan in relation to the whole project to make sure that other site activities will not interfere with transport of

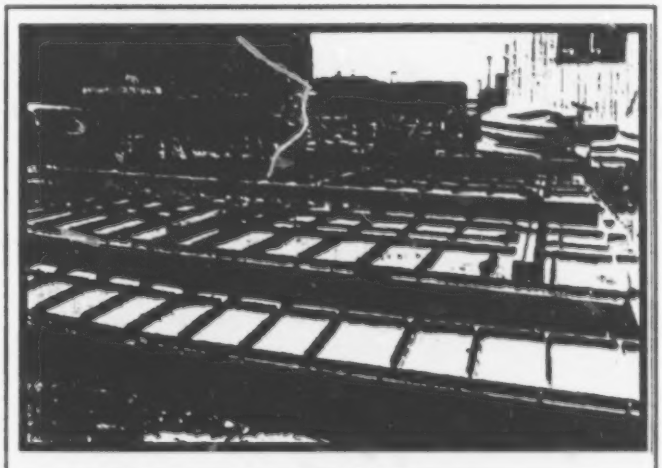


Figure 3-5
The formwork plan must be adapted to the layout of the concrete structure. The use of pre-assembled gang forms on this project will prove economical where large foundations walls are required.

form sections, cause placing delays, or otherwise upset the schedule so that much of the plan's efficiency is lost on the job. The concrete contractor's schedule may have to be adjusted to the schedules of other trades, and this should be taken into account. The critical path method of scheduling can be advantageously used to coordinate complex projects.

Key Areas of Cost Reduction

Economy in formwork construction must be achieved with the basic limitations of safety and quality of construction discussed in Chapter 2. Three major areas of cost reduction will be discussed in some detail in the following pages:

- Planning for maximum reuse
- Economical form construction
- Efficient setting and stripping practices

Savings in first cost of forms must be balanced against other objectives to achieve the least cost on a per use basis. If a form material that costs twice as much lasts ten to twenty times as long, the per use cost will be only 1/5 to 1/20 as much as using the cheaper material. A form designed for maximum reuse may have to be stronger and more expensive than one designed for a single use, but it can save a great deal on the total form investment. Extra features that make erection and stripping easier will add to original form costs, but labor savings may outweigh the extra cost.

It is poor economy to strive for minor savings that can cause big losses elsewhere. For example, increasing design stresses beyond safe limits usually results in small over-all savings while greatly increasing the risk of damage and severe loss. Careless assembly or cheap materials might save a little in form cost but cause much expensive hand finishing of the concrete afterwards.

Planning for Maximum Reuse

The plan or procedure to be followed in getting maximum reuse of forms will vary greatly depending on the conditions of the individual job. Generally the sooner the forms can be stripped, the more economical and practical it becomes to schedule many reuses of a form. Thus specifications or local code requirements for stripping and reshoring are an important factor in planning form reusage. In multistory buildings where forms and shores will be supported by the recently built structural members, special problems must be considered.

Minimum investment in forms is achieved by constructing the least number of forms required for a smooth work flow and then reusing these forms as often as necessary until the job is completed. Since the stripping time for the sides of a beam or girder is much shorter than for the bottom, it is often economical to build fewer side forms and plan on early stripping and frequent reuse of the side panels while the bottom forms are left in place. Chimneys, towers, and cylindrical or rectangular concrete cores for multistory buildings can be built more quickly and inexpensively using slip forms or climbing forms that are reused for many lifts from bottom to top of the structure.

Mass concrete which has a gradually changing cross section can be built using rugged cantilever form panels that are raised and reused for lift after lift. Piers for bridges or viaducts are frequently cast by repeated use of a form or series of forms, while building columns can use the same forms over and over if the building designer has had the foresight to make columns the same size or with fewer dimensional changes. Ready-made modular panels can be moved from one job to another and are adaptable to many different types of structures.

The amount of work involved in reusing a form may depend on whether it has to be disassembled for stripping and reuse. In some cases the form can be moved intact. This is inherent in slip forms, of course, and may be possible with climbing forms or with pier forms that can be lifted off the pier by a crane and set into position at the next pier.

Traveling forms eliminate much of the disassembly and reassembly in reusing formwork. In long barrel construction, for example, it is possible to build the barrel arch form and shoring as a unit with a roller-equipped base. At stripping time the form is lowered from the concrete and simply rolled forward to the next position; this sequence is repeated until the full length of the barrel has been cast. Wood or steel shoring alone may be assembled and braced in units that can be shifted from bay to bay as forms are moved for reuse. Such shoring units must of course be rugged enough to withstand any extra handling and moving stresses and are practical only where conditions and equipment available permit easy, safe handling.

Developing a Practical Reuse Plan
A minimum number of different forms is established by the number of different shapes, sizes, and combinations of concrete members in the structure. Where the same size, shape, or combination is repeated there is an opportunity for reuse, but placing schedule, stripping time, and other factors related to a specific job make it impractical to take advantage of all theoretical opportunities to reuse forms. Thus, if the same size column appears 100 times in a building, theoretically all of these columns could be cast by reusing one form 100 times, but this would not permit a smooth work flow and would extend the construction over an unreasonably long time.

In most cases it is necessary to make a detailed study of work flow and construction sequence to decide on a practical number of reuses that will result in a fast, smooth, efficient job with lowest over-all cost. In simpler cases it may be possible to see immediately the number of forms required and the number of reuses that can be planned. Divide the total structure into unit areas and mark on a key plan the days for erecting forms, setting steel, installing mechanical and electrical work, and placing concrete. Experiment with various sizes of area to maintain steady progress. This will determine the reuse of forms.

Comparing Reuse Schemes
In comparing different schemes, the contractor may calculate the size and number of forms required in each case and find the ratio of form contact area to total area of formed concrete structure. This ratio is an indicator of over-all reuse efficiency, although it does not necessarily indicate the number of reuses of a particular form in the plan. In comparing two plans, where one has more reuses than the other, the contractor should take into account the time and cost of repairs and reconditioning between uses. Forms often have to be cleaned between reuses, and a vibrating tool, for example, may damage the contact surface of a form so that a panel must be replaced before the form can be reused.

Economical Form Construction
In evaluating different schemes to get maximum reuse of forms and an efficient construction sequence, the contractor must make an estimate of form construction cost for each plan. He also may choose between building the forms himself and buying or renting them. One plan may require many forms while another uses fewer forms of a more expensive type. A reasonable cost estimate requires a practical construction plan to determine which is more economical.

Job-Built Forms
When non-reusable forms are to be built in position on the job, the contractor plans to use inexpensive materials that are easy to transport, handle, and shape in the field. Reusable forms must be more durable, made of strong materials that can withstand continuing usage, and usually must have added features that make them easy to handle and to assemble.

Materials and Hardware
In choosing ties or inserts, the initial cost is not as important as the labor involved in their installation

Figure 3-6 & 3-7
The contractor must decide which type of forming system is best suited for each particular job. Shop built (left) forms may be better suited for some jobs than ready-made form panels (right).

and form stripping. In considering the type of materials to be used in construction of the forms, the contractor will keep in mind materials on hand and compare with the economics of purchasing or renting new materials. Thus, if large quantities of 2x4 studs are available, it may prove more economical to use them, spaced closer together, than to purchase 2x6's.

Using plywood panels for large surfaces usually saves money (as compared with board sheathing) because there is less assembly work, and with fewer joints in the form surface less concrete finishing is required after the forms are removed. Use of 4x4's instead of 2x4's on edge may be more economical since the 2x4's would have to be held in position and toenailed into place.

The contractor may have to choose between partially absorptive form materials like standard plywood and dressed lumber that produce a slight texture; hardboard, plastic, plastic-coated plywood, or metal forms that produce smooth surfaces; or purposely rough wood forms that produce a distinctive texture. Specifications must be carefully studied and possibly discussed with the architect-engineer to see just what effects he wishes.

Better grades of lumber and plywood can be counted on for minimum waste and to a great extent are reusable, but sometimes a saving can be made by purchasing a lower grade of lumber and culling at the building site. Whether this saves in over-all cost depends on how much labor must be expended in the culling and in cutting and splicing to get maximum use of material. The decision may depend on the location of the job and the supply available.

Where good materials are required, a saving can be made by obtaining materials for the current job that can be reused on future jobs. Thus it may be economical to invest in high grade reusable panels, sections, materials, and hardware and prorate only a part of their cost to the current job.

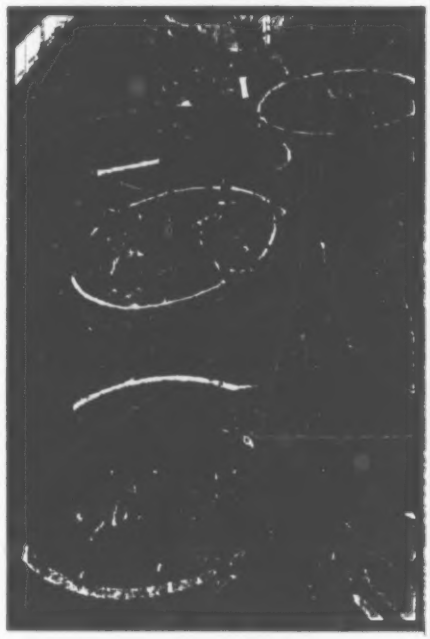


Figure 3-8
The type of hardware the contractor chooses will depend more on the amount of labor time saved than the initial purchase cost of the hardware.

Where to Construct Forms

In most jobs the contractor has a choice of building forms in position on the job, setting up a special shop or assembly area on the site, or building all the forms in a central shop and shipping them to the site. For many jobs the greatest efficiency in working conditions and in the purchase and use of materials and machinery is obtained by fabricating form sections in a central carpentry and welding shop maintained by the contractor at his headquarters. The cost of transporting form sections to the site may make this plan uneconomical if the shop is located too far from the job, and of course, if form sections are too large for shipping, they must be built at the site. At times, however, space on the site is so limited that off-site fabrication is the only feasible method.

For small jobs, or where forms must be fitted to the terrain, it may be economical to cut and assemble at the point of installation where cut-and-try methods can be used, in spite of the waste which usually occurs under such conditions. Most job-site form building, however, will benefit from special working conditions and equipment. A shop or at least a sheltered area can be set up and equipped with power tools and assembly benches. If necessary a platform can be built alongside the shop for assembly of large form sections. The job-site shop should be located so that form materials can be conveniently stored near the shop and where there is access for transport equipment to pick up the finished form sections.

Possible savings through reduced waste of material and better productivity of labor are usually in direct ratio to the amount of work which can be done shop-performed. Shop fabrication reduces problems of planning and control since supervision is easier if the only work done at the point of installation is assembly of forms.

Estimating Form Building Costs
Before a formwork plan is actually chosen and the forms designed in detail, a rough estimate of formwork construction cost should be made. It is possible to determine roughly the number of board feet of timber necessary to produce a square foot of contact area by examination of similar types of forms used in previous work. Allow for waste material cut off as well as wales, scabs, strongbacks, and other materials attached to the form. Multiplying by the expected price per board foot of lumber gives an estimated basic material cost per square foot of contact area. For this rough estimate, plywood is sometimes considered to cost twice as much per square foot as unfinished lumber. Material such as steel beams and heavy timbers on hand in the contractor's yard which will have value after the job is finished should be priced at a "use charge" that is a percentage of their original value. Average labor cost for constructing forms may be available from records. If not, a simple analysis of crew and operations may be converted to manhours per square foot. The price per manhour should be a weighted average of expected labor rates of foremen, journeymen, apprentices, and helpers in addition to other crafts that may be directly involved in construction of the forms.

To the foregoing labor and material figures must be added allowances for hardware and other miscellaneous materials as well as the cost of receiving and handling materials onto the site and the cleanup or preparation of used material. The total cost must be divided by expected reuses to make a direct comparison between alternate formwork plans.

Purchased or Rented Forms
The contractor's estimated cost for building forms may be compared with bids or estimates from suppliers who will build the forms for him or who will rent prefabricated forms. Many contractors find rental of forms for specific usage permits them better flexibility in regulating the volume of work they are able to assume. Passing on the risk, investment cost, and some of the management responsibility to a form-work subcontractor may make the whole operation go more smoothly. Consideration of cash flow may influence the decision; since items such as column molds, fasteners, spacers, and ties will be included or will be offered by the supplier on a rental basis, the contractor can eliminate an investment in such stock items. The contractor may find that consulting with form suppliers will help develop an imaginative approach to formwork planning that will save time and cost.

Figure 3-9
Setting and stripping of forms must be a part of the formwork plan. Special hardware used in this forming system provides fast set-up and stripping of wall forms.

A careful analysis of all formwork required may show that the contractor can economically build some of the forms while others should be obtained from specialists. Those intended for a large number of reuses, for example, which must withstand much handling, may be purchased from a supplier of prefabricated steel forms. The purchase price or rental of the forms plus any handling or preparation expenses should be figured on a per square foot of formed area basis to make a valid comparison with other alternatives.

Setting and Stripping
The cost of setting forms in place and subsequently stripping them from the concrete is an important factor, and substantial savings can be made by design and planning provisions that make erecting and stripping easier and faster. The full benefit of a plan for reuse of forms can only be realized if the forms can be stripped and re-erected without too much lost time and if the form is not wrecked in the process. Therefore designing for easy handling and disassembly is essential. The total formwork plan should, if possible, permit repetition of the same functions to increase the crew efficiency as the job progresses.

Formwork can be assembled with metal clamps or special wedge pin connections that are secure, yet easy to assemble and disassemble. Handles or a

wood strip nailed to the form give workers a means of grasping the form side so they can pull it away from the concrete and thus eliminate or minimize the need for prying it loose. Lifting eyes and other hardware make it easy to transport the form sections from one placing location to the next. Scaffolding and platforms to make both erection and stripping more convenient and safe for workers should be part of the formwork plan.

Erecting and Stripping Cost Factors
In comparing the expected erecting and stripping costs for various formwork plans, estimates may simply be based on manhours per square foot as shown by previous experience with similar types of forms. A more detailed comparison might be made through an analysis of crew size, specific operations, and time from start of stripping of a form until it is ready for the next placement. This detailed approach would be particularly valuable for the major forms on a job, including those with a large number of reuses.

Total time in hours multiplied by the number of men in the crew gives the total expected manhours. The contact area formed at each placement divided by the estimated manhours gives a production rate in square feet per manhour. This figure should reflect average conditions over a representative period and therefore should include allowance for delays resulting from poor weather, equipment breakdowns, and other causes. Any miscellaneous expense normally incurred should be allowed for, including the cleaning and oiling of forms between uses. Some allowance must also be made for the routine nonproductive time of the workers.

Many formwork plans will anticipate raising a form and locating it by inserts in the previously placed concrete or using inserts as a means of anchoring, lifting or attaching it. Ties, spacers, and other hardware items also may be left in the concrete. So allowance must be made for hardware lost or left in place in the concrete plus other non-reusable material expended during the process of placing and removing the forms.

Other Costs Affected by Formwork Plan
The ultimate objective in selecting a formwork plan is to achieve good, safe performance at the lowest over-all cost for the whole project. Since formwork cost is often a large part of the total cost of erecting a concrete structure, it is easy to assume that a plan that produces the lowest total formwork cost also will result in the lowest over-all cost for the total concrete work. However, the other cost factors in a concreting project, including the efficiency of concreting, reinforcing, and concrete finishing crews, and the use of cranes, hoists and other equipment, are affected by the formwork plan, and could be the deciding factors between two alternate plans. Possible effects of the formwork plan on job costs outside of the concrete contract must also be considered.

Crew Efficiency
Advance planning eliminates confusion and delay in the field, where it is most costly. Where maximum reuse of forms is emphasized, every operation must be scheduled precisely to sustain effective continuity of employment of craftsmen on the site.

The contractor must decide on a reasonable day's work for setting forms and placing concrete. It is poor economy to force a fast pace over short periods with intermittent stoppages, causing concreting, form stripping, and reinforcing crews to keep each other under pressure between delays. True economy comes from a smooth daily repetition of the same operation. If a reasonable schedule is planned, and allowance made for familiarization, each crew will become fast and efficient; the superintendent will be able to concentrate on scheduling of men and materials, and fewer panic situations will arise to disrupt schedules and lead to errors. In the long run the job will be completed faster and at lower cost.

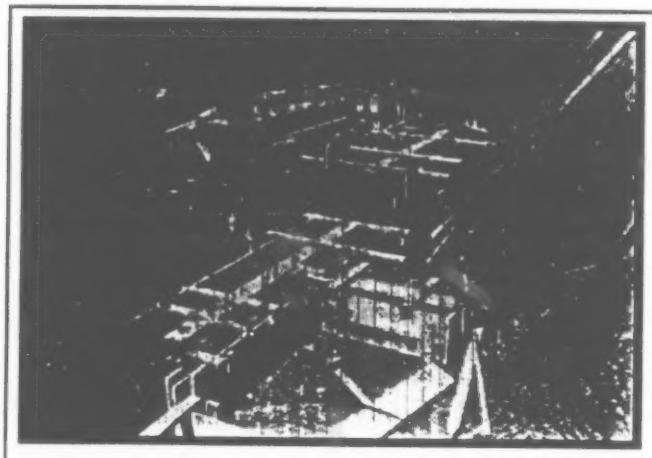


Figure 3-10
Footing forms built in-place to conform to irregular foundations requirements.

Concreting

The ease and speed of placing concrete is related to the planned sequence and to some extent to the choice of form design. High lifts in wall construction may save money in setting and stripping forms but make placing and vibrating difficult. High rates of placing may require a heavier form to withstand the loads, and conversely placing rate is limited by the form design.

If the planned placing schedule will not permit the concreting crew to spend a full day on the job, the contractor is faced with a choice of:

1. Increasing the placing schedule by making forms and lifts larger or using more forms with fewer reuses.

2. Making other assignments available to the concreting crew to take up the slack.

3. Allowing for less than full effectiveness on the job.

Size of placement units may be predetermined by construction joint specifications; if so, the contractor should plan changes only in consultation with the architect or engineer.

Bar Setting

Crews installing reinforcing steel will be used most efficiently if their work can be scheduled to fit the concreting sequence without causing lost time in either the concreting or bar setting schedule. Where possible, if the form design can permit the reinforcement to be preassembled before installing, it may enable the reinforcing crew to work under more favorable conditions, and they can work at their own pace without lost motion. Their work then can be scheduled ahead of form setting, so that forms can be set one day and concrete placed the next, thus speeding the schedule and possibly increasing the number of form reuses.

Other Trades

The contractor's plan should coordinate the work of other trades, such as electrical and mechanical, with the concreting schedule, not only to permit these other trades to perform their work efficiently but to minimize interruptions in placing.

Cranes and Hoists

One object of planning should be to use cranes and hoists efficiently so that there are just enough on a project to keep the work going smoothly. The amount of time that a crane is tied up in moving and erecting formwork will determine the extent to which it may be available for other work on the project. If this "free" time is too little, then an extra crane will be required for other operations. Careful scheduling of material handling plus a form erection sequence that requires the least movement about the project site will save crane time. Mobile cranes must have access to and from the job, and it may be necessary for the contractor to schedule the placing sequence so that one bay is left open to permit crane and concrete truck movement until the last form is set in place. This access requirement may influence formwork design, requiring large shores spaced some distance apart.

One approach to efficient use of cranes is to determine what cranes are necessary for other functions, then see if a formwork plan can be established that will permit use of one of these cranes for erecting forms during otherwise idle time. It may be worthwhile limiting the size of form sections to the capacity of the largest crane that the contractor owns or would have on the site for other purposes. Or, if a very heavy crane is needed for lifting and placing form sections, it may be possible to so schedule its use that it can handle all heavy work on the project, and thus some small truck-mounted crane may be used for the rest of the work. Or it may be possible to use a single crane for all functions, including handling of forms and materials, and placing concrete.

In some cases traveling cranes already installed in a building may be used to position forms, thus freeing mobile cranes for other work. Some jobs are planned to complete elevator and stair towers early in the schedule so that they can be used for moving men and materials.

SECTION IV: SITE PREPARATION

Pages 53 - 56	Soils and Compaction (Laborers-AGC TIPS #8)
Pages 57 - 58	Article 9: *Subgrade Preparation*
Pages 59 - 60	Article 10: *Basics of Subgrade Preparation for Industrial Floors*
Pages 61 - 63	Article 11: *Soil Compaction in Residential Construction*
Pages 64 - 65	Article 12: *Laying Out the Site*
Page 66	Article 13: *Building the Footings*

Trainee Section Objectives

1. To become aware of the importance of soil compaction.
2. To demonstrate proper procedures to prepare and compact subgrade material.
3. To demonstrate competency in laying out a project.
4. To demonstrate competency in constructing footing subgrade and forms.

LABORERS-AGC TRAINING TIPS

No. 8

TRAINEE INFORMATION PROFILE SERIES

SOILS AND COMPACTION

- SOIL TYPE
- MOISTURE CONTENT
- HEIGHT OF LIFT
- METHOD OF COMPACTION

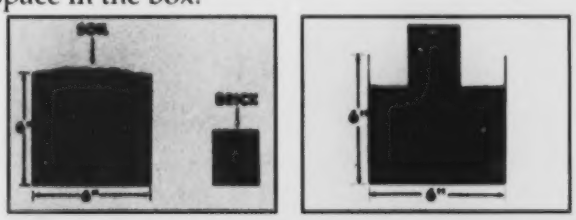
Compaction is one of the most important jobs performed on a construction site. Unfortunately proper compaction is sometimes taken for granted. When done correctly a compacted surface provides a solid base for buildings, highways and pipelines. When rushed or improper methods are used it's like a time bomb waiting to go off.

This manual is designed as a supplement to the video "SOILS AND COMPACTION" and to the hands-on training you will receive at your local training site. We have highlighted the main points to remember. Your instructor will see that you get additional information.

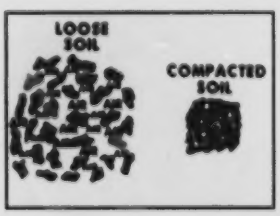
When you complete your training, this book will serve as a reminder of what you've learned. If you put all the information received during your training into practice on the job, you will benefit your Union, your Employer and most of all YOURSELF.

A SMALL DEMONSTRATION

In this demonstration a brick was used to tamp down loose soil in a box. Once the dirt was completely tamped down, it occupied less space in the box.



Two things happened to the loose soil; the brick rammed the particles of soil closer together and air trapped between the particles was forced out.



This process of tamping with a brick to make the dirt occupy less space and become firm and hard is called, COMPACTION.

Compaction is necessary to get a solid base for buildings and structures. Without compaction, foundations would settle and walls would crack. Highways would crack and pipe lines would break.

THE PROCESS OF COMPACTION

Four things influence the process of soil compaction:

- soil type
- moisture content or the amount of water in the soil
- the height of the lift, or the thickness of layers of loose soil to be compacted
- the method of compaction

Lets examine each of these.

Soil conditions vary throughout the country. Certain regions are primarily either sand or clay. In most areas the soil is usually mixtures of gravel, sand, clay, silt and loam. Silt is very fine and smooth ground rock. A good example of silt is the material deposited at the drainage end of pipes and culverts. Loam is a mixture of sand, silt and clay. An example of loamy soil is river bottom topsoil.

In the process of compaction we are concerned with three kinds of soil:

- Cohesive
- Partly-Cohesive
- Non-Cohesive, or Granular.

Cohesive soils are loam and clay, soils that bind or stick together.

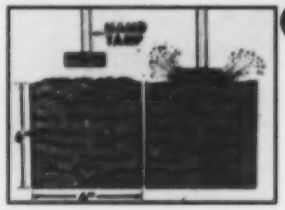
Partly-Cohesive soils include sand-clay mixes, silt and mixtures of sand and silt.

No-Cohesive or Granular soils are sand, gravel and mixtures of sand and gravel, soils which do not stick together.

MOISTURE IS A MUST

Soil moisture is important in compaction. If there is too much water in the soil, it will "pump" and not compact. When you push wet soil down in one place, it will "pump" up in another.

If the soil is too dry, it will "fluff" up and you still won't get compaction.



The right amount of water in the soil acts as a lubricant (or oil) on the particles. Compacting properly watered soil makes the particles slide very close together forcing most of the air out.

When you add water to soil, you can tell if the moisture content is about right by squeezing a handful of the dirt. If it takes and holds the shape of your grip, it has the right amount of water.

TYPES OF COMPACTORS

The machines used by laborers compact the soil in three basic ways:

- By Impact - a ramming action which forces out the air and drives the soil particles together.
- By Vibration - which shakes the particles closer together and forces out the air.
- By a Combination of these two methods, Impact and Vibration.

Vibratory machines work best with granular or non-cohesive soils such as sand, gravel and mixtures of these.

Partly cohesive soils such as sand-and-clay mixes, silt and sand-silt mixes are best compacted by those machines that use the combined impact-vibration method.

Machines with a pounding action should be used when compacting cohesive soils such as clay and loam, or mixtures that are mostly clay.

BACKFILLING

The height of the lift, or backfill layer of loose soil to be compacted, also has to be considered. Your labor foreman will tell you what size the lift should be. They usually range from 6 - 12 inches.

"Fill" has to be clean, free of roots, cans and other debris, that could rot or rust and leave holes in the compacted soil.

The lift has to be leveled off each time fill is placed, before you start compacting. It's much harder to run a machine over a surface that is not level.

Before compacting around pipe remove any large rocks that are against it. Avoid hitting the pipe with the compactor and make sure there is enough fill on top of the pipe

Remember - the factors that influence soil compaction vary: the type of soil, the moisture content, height of lift and method of Compaction. To compact effectively, you must consider all of these factors on each job.

KEY POINTS TO REMEMBER

- KNOW THE SOIL YOU ARE WORKING WITH.
- PROPERLY WATER THE SOIL TO BE COMPACTED.
- USE THE RIGHT COMPACTOR FOR THE JOB.
- BACKFILL ONLY IN RECOMMENDED LIFTS.
- USE CAUTION WHEN COMPACTING AROUND PIPE.

General Occupational Safety and Health Regulations
Soils and Compaction

ITEM	REFERENCE
Personal Protective Equipment (Head, Foot, Hand, Hearing, Eye/Face, Respiratory)	29CFR 1926.28
Hazard Communication	29CFR 1926.59
General Safety and Health Requirements	29CFR 1926.20
Safety Training and Education	29CFR 1926.21

Additional standards may apply when used in special construction activities such as demolition or tunnels and shafts.

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Article 9: Subgrade Preparation

The first step in building a walk, drive, or slab is preparation of the subgrade. This is a most essential step for building any slab on ground. Serious cracks, slab settlement, and structural failure can very often be traced to a poorly compacted subgrade. The subgrade should be uniform, hard, free from foreign matter, and well drained.

Remove from the site all organic matter such as grass, sod, roots, etc., and grade the ground (Figure 4-1). Dig out soft or mucky spots; fill them with soil similar to the rest of the subgrade, or with granular material such as sand, gravel, crushed stone, or slag; and compact thoroughly. Loosen and tamp hard spots to provide the same uniform support as the rest of the subgrade. All fill materials should be uniform, free of vegetable matter, large lumps or stones, and frozen soil.

Figure 4-1
The first step in preparing the subgrade is to remove all sod, roots, and debris.

Granular fills of sand, gravel, crushed stone, or slag are recommended for bringing the site to uniform bearing and final grade. Compact these fills in layers not more than 4 in. thick. It is best to extend the fill at least 1 ft. beyond the slab edge to prevent undercutting during rains.

Figure 4-2
Hand tampers are suitable for small jobs. For best compaction, sand or gravel fill should be used.

For subgrades that are water-soaked most of the time or poorly drained, cover, with 4 to 6 in. of granular fill . The bottom of this granular fills must not be lower than the adjacent finished grade to prevent the collection of water under the slab.

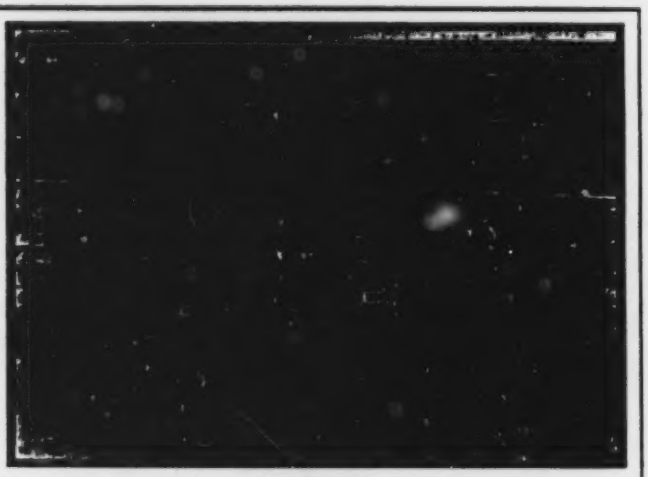


Figure 4-3
Vibratory compactors are practical for all but the smallest jobs.

Unless fill material is well compacted, it is advisable to leave the subgrade undisturbed. Undisturbed soil is superior as support for a concrete slab to soil that has been dug out and poorly compacted.

Figure 4-4
Vibratory rollers are recommended for large projects.

Subgrade compaction can be done with hand tampers (Figure 4-2), rollers (Figure 4-4), or vibratory compactors (Figure 4-3). For the small job, hand tampers may be used, but for large-volume work such as a large driveway, sidewalk, or building slap, mechanical rollers or vibratory compactors are strongly recommended.

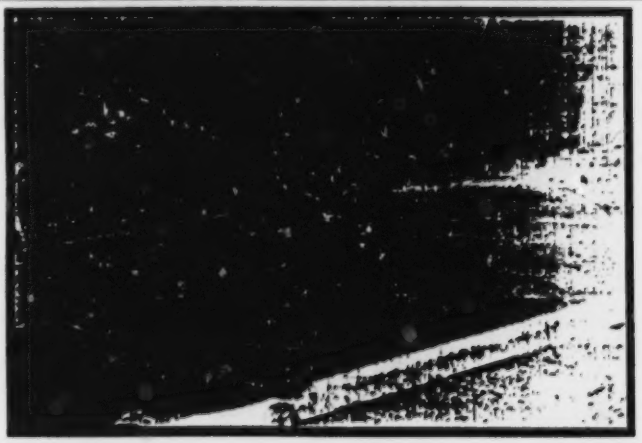


Figure 4-5
Immediately before concreting, dampen the compacted subgrade by spraying with water.

A dry spot on the subgrade absorbs more water from the concrete slab than does an adjacent moist spot. This, in turn, may result in dark and light spots in the concrete finish. Hence, the subgrade should be in a uniformly moist condition at time of concreting. If necessary, dampen it by spraying with water (Figure 4-5). However, there should be no free water standing on the subgrade, nor should there be any muddy or soft spots when concrete is being placed.

Article 10: Basics of subgrade preparation for industrial floors

by Boyd C. Ringo
Consultant
Chairman, ACI Committee 360,
Design of Slabs on Grade
Cincinnati, Ohio

Place a concrete slab on any unstable subgrade and you'll probably pay for it two ways. During construction you'll either waste concrete or build a floor that's too thin in spots because the subgrade surface is uneven.
After construction, the floor is likely to settle and crack because of poor subgrade support. Strengthening the subgrade can be costly and time-consuming once the floor is in place, so it makes sense to place the slab on strong and stable soil at the start.

Identify unsuitable soils and subgrade conditions
Investigate soil conditions before the floor is built. The grading contractor is responsible for making sure a concrete floor is placed on adequate support. A geotechnical engineering firm that inspects the site and takes soil samples can supply data needed for design and construction decisions. Needed information may include:

- Types and conditions of soils (both site soils and borrow materials)
- Soil properties (grain size, liquid limit, plastic limit, plasticity index, moisture-density relationship)
- Water table elevation
- Drainage conditions

Organic soils such as peat, muck, and organic silts or clays are not suitable subgrade materials. They are weak, compressible, hard to drain, and can't be adequately compacted. Fortunately they're often near the surface where they can be removed along with sod, roots, and other organic material. However, they also may be present well below grade. Make sure that any fill materials also are free of organic matter. Some clayey soils make unsuitable subgrades because they swell or shrink with changes in moisture content. Soil test results, especially the plasticity index (PI), are helpful indicators of swelling potential. As the PI increases above 10, swelling potential also increases.

Figure 4-6
Compaction of this graded granular fill improves subgrade support for slabs on grade by decreasing void content.

Improve the subgrade soil
Compaction improves the properties of all but the organic soils by decreasing void content. This increases soil strength and reduces the chances of rutting during construction or settlement later. Laboratory tests may be run to find the optimum moisture content that yields maximum density of compacted find-grained soil . Expansive soil compacted at a moisture content several percent above optimum isn't as likely to cause shrinkage and swelling problems.

Pay particular attention to soil compaction in utility trenches and near footings. Carefully compact backfill so there aren't any soft spots. If compaction isn't uniform, the slab may crack as it bears on the hard spots and bridges the soft areas.

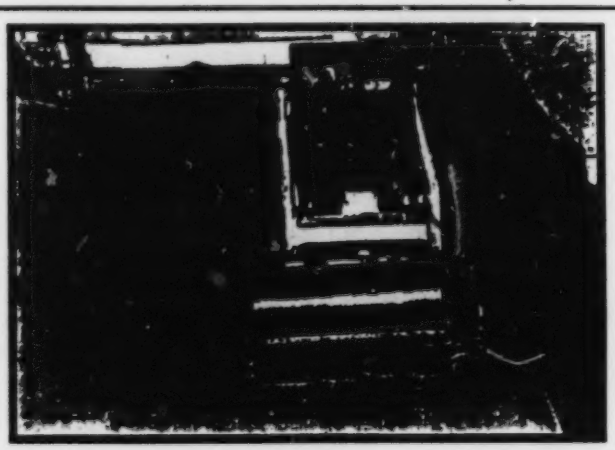


Figure 4-6
Pay particular attention to soil compaction in utility trenches and near footings.

If soils are highly expansive, consider soil stabilization. Sometimes it costs less to stabilize an expansive soil than to remove and replace it. Lime or portland cement can be mixed with some clays to reduce the plasticity index and improve performance. There also are proprietary chemicals that are injected into the soil to stabilize it.

Inspect subgrade preparation methods during construction

For floors placed on fills, observe the earthwork operations from start to finish. Make sure the fill is placed on firm soil and that all layers are firmly compacted. Upper layers can't be properly compacted if they're resting on a soft support. Check the quality of fill materials being placed and the loose thickness of layers. Use field density tests to verify that specified density is achieved. Remove soft spots in existing soils or fills. Backfill with adequately compacted replacement soils.

Figure 4-6
Field density tests will verify whether or not specified compaction has been achieved.

Make sure that correct compaction equipment is being used. Vibratory rollers or flat plate vibrators are best for granular soils. Sheepsfoot rollers work best for clay soils, and rammers can be used in confined areas.

Supplement field density and moisture content tests with visual observation. An experienced inspector can form a small ball of the soil by squeezing it in his hands, then breaking it apart between two fingers and a thumb. If the ball breaks cleanly without crumbling, moisture content is at near optimum.

Under winter conditions, when frozen materials are likely, don't use frozen materials for fill and don't place fill on frozen ground. Anytime the temperature drops below 25°F, take precautions to prevent freezing of the soils being placed; or of the ground on which they're placed. Also, don't place concrete on a frozen subgrade.

Control subgrade elevation

Correct subgrade elevation ensures that floor thickness will be uniform. Often the subgrade is rough graded to plus or minus a 10th of a foot and a granular subbase is then used as a leveling course for fine grading. The subbase surface should be no more than 3/8 inch above specified elevation after fine grading.

The subbase must be compacted to specified density before concrete is placed. Otherwise the base will shift and deform during concrete placing, causing the floor thickness to vary.

Check final subgrade or subbase elevation before placing concrete. Use a scratch template, stringline, or elevation shots with a level.

Deal with compaction problems immediately

If field compaction test results are unacceptable, find the cause and correct it before the job has gone so far that correction is too costly. There are several possible reasons for compacted densities being below specified values.

- Soil too wet or too dry (must be near optimum moisture content)
- Layers of soil are compacted too thick
- Improper compaction equipment or methods (rollers too light, not enough passes)
- Not enough tests taken
- Laboratory density tests on soil sample not representative of soil being used in the field

A prejob conference is a good time to discuss both the compaction methods to be used and the frequency of tests. Good subgrades don't just happen. They're properly planned, constructed, and tested.

Article 11: Soil Compaction in residential construction

Low-cost insurance against high-cost problems

It's not hard to spot some of the results of poor soil compaction around a house. Cracked foundations. Concrete steps that lean away from the house. A cracked and settled garage slab with one part higher than the other. Rain water running toward the foundation instead of away from it.

compacted soils. Excessive soil settlement under footing and slabs can cause major structural problems, but settlement is undesirable even if there's no structure on the soil. Failure to compact the backfill next to a wall, for instance, can cause the fill to settle, creating a low spot that traps water next to the wall. Many leaking basement problems are caused by this kind of drainage problem,

Slowing water movement into and out of the soil is another compaction benefit in areas with swelling soils or soils that heave when frozen. Swelling soils

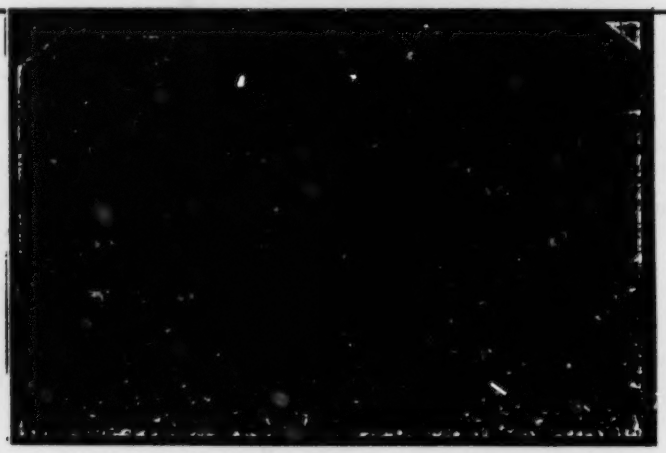


Figure 4-9 & 4-10
Failure to compact subgrade soil or granular base material can cause settlement and concrete cracking.

All these flaws mar appearance and reduce resale value for the property but could have been easily avoided without spending a lot of money. Compacting the soil during construction costs much less than correcting settlement problems after they occur.

Why compaction is needed?
Compaction reduces the amount of air pockets or voids in soil by packing the solid particles closer together. Forcing as many solids as possible into a given space increases soil density and strength. Increased strength lets the soil carry greater loads on footings of a fixed size or permits using smaller footings for a fixed load.

Well-compacted soils won't settle as much as poorly

expand when they get wet and shrink when they dry. Frost-susceptible soils, if they freeze while saturated, can cause enough pressure to crack a wall or push up a slab. Well-compacted soils don't give up water as easily and shrink during dry weather. Nor do they soak up water as fast during wet weather. Thus they don't swell as much as poorly compacted soils and aren't as likely to cause damage when frozen.

Where is compaction needed?
Use compaction whenever the soil is disturbed during construction or when it's used for fill. If organic soils are present, remove them first. Then compact disturbed soil beneath footings, slabs, basement floors, patios, garage floors, driveways,

concrete steps and sidewalks. If a sand, gravel, or crushed stone base is used beneath a slab, compact it too.

Always compact fill soils before placing footings or slabs on them. Compact soil under and around buried water and sewer pipes. Also compact backfill next to footings and foundations walls. Soils in fills will settle if they're not compacted.

Sometimes it's more economical to replace soft cohesive soils with clean granular fill rather than having to compact many thin lifts of the cohesive soil. But don't make the mistake of just dumping a load or two of gravel, crushed stone, or sand into the hole without compacting it. Whether the material is of a single size such as pea gravel, or a graded material, it still has to be compacted. A thick, uncompacted layer of granular material may settle an inch or more.

Effect of soil type and moisture content.
For compaction purposes, soils are considered to be either granular or cohesive.

Granular soils contain primarily gravels, sands, and silts and feel gritty when rubbed between the fingers. They have little or no plasticity when wet and no cohesive strength when dry. The dried material crumbles readily. Well-graded granular soils (good particle size distribution) compact to a higher density because smaller particles fill the voids between larger particles.

Cohesive soils contain clay and feel smooth and greasy when rubbed between the fingers. Cohesive soils are plastic and sticky when moist and have a high dried strength. Highly plastic cohesive soils are hard to compact.

Dry cohesive soils don't compact at all. Adding water to the dry soil lubricates the particles and makes the soil compact better. For a fixed compactive effort, density increases as moisture content increases up to a point. But if too much water is added it starts taking up space that could be occupied by solid particles. Then the density goes back down. The best or optimum moisture content for compaction is the one that produces the highest density.

To determine the optimum moisture content, soil samples are mixed with differing amounts of water and compacted using a standard method. The dry density and moisture content are measured and plotted on a graph. The moisture content giving maximum dry density is the optimum moisture content.

Tests for determining maximum dry density and optimum moisture content should be run by a qualified testing laboratory. A laboratory inspector also should measure soil density and moisture content of compacted fills to ensure adequate compaction.

Choosing and using the right compaction equipment
Strip away organic or spongy soils before beginning to compact fills. Compaction must start on a layer that is itself sound and compact. Don't try to dispose of construction debris, branches, or other organic materials by covering them with the fill.

For large fill areas, rolling is the fastest, most efficient compaction method. Use a smooth-wheeled or grid-wheeled vibratory roller for granular soils or with a sheepsfoot roller for cohesive soils. Cohesive soils must be compacted at or near optimum moisture content. Water may be added to the soil to increase the moisture content, or the soil may be aerated with a disc harrow to dry it.

Hand-held compactors can be used in smaller areas and for places that larger mobile equipment can't reach. When compaction is needed near foundations or walls, hand-held equipment is less likely to damage newly placed concrete. For best results, though, you still need to match equipment with the soil type being compacted.

For granular soils, vibrating plate compactors work best. Vibration decreases friction between particles, allowing fines to sift downward and fill voids between larger particles. For most vibrating compactors, frequency (number of blows per minute) ranges from 1,600 to 6,100. Use vibrating compactors with a high frequency for fine to medium sands. Use heavier weight, lower frequency compactors for coarse sands, gravels, and mixes containing some clay.

Rammers or impact type machines are used for cohesive soils. Rammers pound the ground with a much lower frequency than vibrating plate compactors, but the amplitude (vertical rise) is higher. Rammers work through a jumping action that squeezes the soil particles together. They

deliver 450 to 800 blows per minute through a spring mechanism in the hand-held versions.

Rammers also can be used to compact granular materials, but only if the material is in a confined area such as a trench. If the area is unconfined, a rammer pushes the granular soil to the sides rather than compacting it.

Vibrating plate compactors and rammers can be rented from construction supply companies. If you need higher production rates for large areas, vibratory rollers also can be rented.

Some builders view the equipment and labor costs for soil compaction and testing as an unnecessary expense. But compaction certainly costs less than the repairs needed to correct problems caused by inadequate compaction.

Figure 4-11
Use rammers for compacting cohesive soils such as clay.

Article 12: LAYING OUT THE SITE

Site layout refers to the process used to determine precisely where the outside edge of the foundation will be located. This is done primarily through the use of batter boards.

The structure should be roughly positioned first with a stake at each corner. Stretch a string from stake to stake. Use a carpenter's square to roughly determine each right angle. Then see how close to square it is by measuring the diagonals. A building layout is square when the diagonal measurements are equal. Move the stakes until the measurements fall within a couple of inches of being square. The actual squaring occurs with the batter boards.

Constructing Batter Boards

Batter boards are located at all four corners and consist of 2 by 4 stakes connected by 1 by 4 boards. Use a framing square to construct the batter boards at 90-degree angles, but don't waste hours being exact. However make sure the stakes are driven firmly into the ground so the boards are stable. You will be pulling twine on the batter boards and if they wobble or shift your work will be inaccurate.

Two things are important about batter boards: where you position them and how you level them. On a small job, where you will be digging the footing ditch by hand, place the batter boards 4 feet out from the rough perimeter strings. If you are going to dig your ditches with a backhoe, either set them 2 feet back so the backhoe operator can reach over them or set them 10 feet back so the operator can maneuver inside them.

Leveling Batter Boards

For an accurate layout the tops of the crosspieces on the batter boards should all be the same height. On small jobs, such as a 12-foot by 12-foot workshop, the tops can be leveled with a line level.

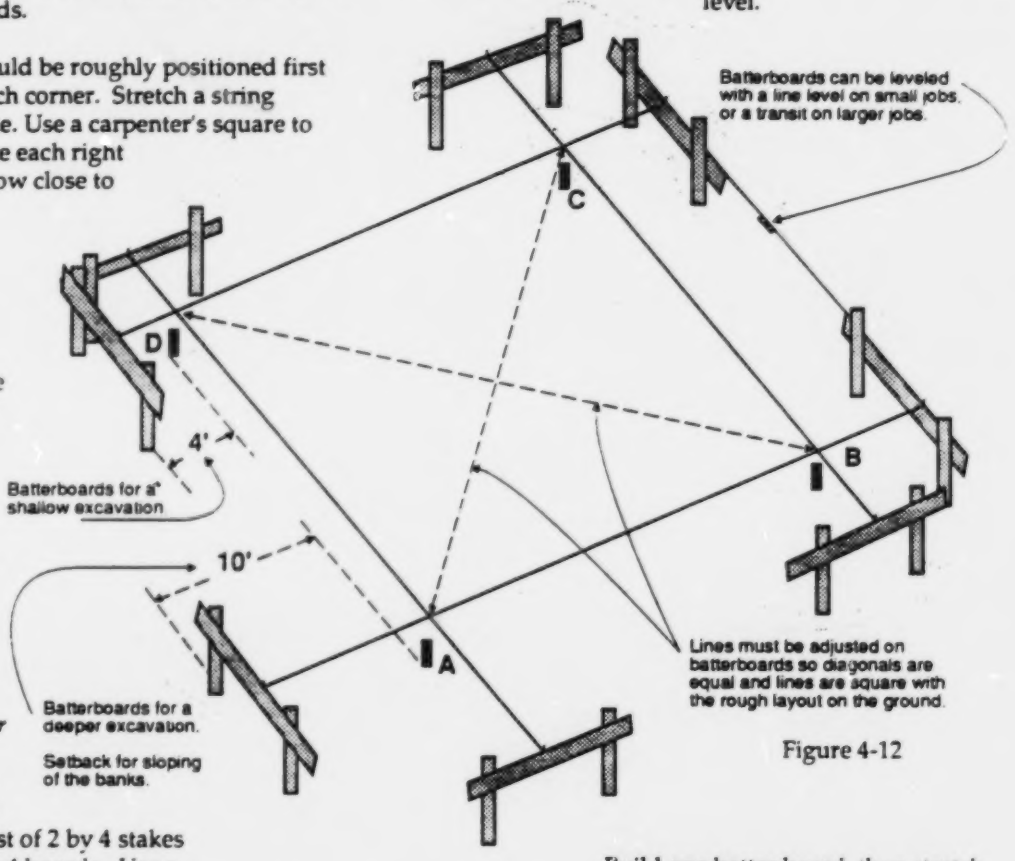

Batterboards can be leveled with a line level on small jobs, or a transit on larger jobs.
C
D
4'
Batterboards for a shallow excavation
B
10'
A
Batterboards for a deeper excavation.
Setback for sloping of the banks.
Lines must be adjusted on batterboards so diagonals are equal and lines are square with the rough layout on the ground.

Figure 4-12

Build one batter board, then stretch twine to the other stakes and make a pencil mark on them where level. Nail the cross-pieces to the stakes.

On larger jobs, twine cannot be stretched tight enough for accurate leveling. Here you can quickly and efficiently find the level with a transparent plastic hose or a hose leveling attachment found in most large hardware stores. This consists basically of some clear plastic tubing that fits over each end of a hose. To use it, first build a batter board at one corner, using a level to make sure both crosspieces are level. For a poured perimeter foundation, the tops of the crosspieces should be the same height as the top of the foundation wall. Build this first batter board at the highest corner of ground when working on sloping terrain. Fill the hose with water - in fact,

let it overflow to make sure no air bubbles are trapped in the hose - then hold one end so the water line is level with the top of the crosspiece. Have a helper take the other end of the hose to the stakes driven at the other corners. Mark each stake at the water line, then nail the tops of the crosspieces flush with these marks.

Faster and more accurate than the hose device is the builders level. This is basically a small telescope that remains perfectly level as you move it. Set the tripod far enough back from the low corner of the building site so that you can see all four corners when you move the builders level. Use the bubbles on the sight to level the transit. Move it back and forth and double check that it is still level. Now set the batter board stakes at all four corners, but do not put on the cross pieces. Starting with the stakes at the highest corner of the site, center the builders level sight on one of the stakes or a grade rod. Have a helper mark the stake where the cross hairs are centered or record the rod reading.

Turn the level to each succeeding corner and repeat this process. Nail the crosspieces to the stakes with the tops flush with the lines (or at the same rod reading), and they will all be level.

Stringing the perimeter

Once the batter boards are in place, stretch twine between the batter boards to mark the outside edge of the foundation. Stretch the first string above the rough string layout you have on the ground for the outside of the building. Everything else must be square with this line. Drive small nails in the top of the crosspieces and attach the string to the nails.

The twine must be pulled extremely taut to eliminate any sags. To tie off twine on nails in a crosspiece, use the technique shown; then, without cutting the twine, cross over to the other crosspiece, tie it around the nail and string the next leg.

Pull the next leg at right angles to the first by using the 3-4-5 method. Do the same on the succeeding legs. Now, to check your work, first measure the building dimensions, then measure the diagonals. Adjust the strings until the diagonal measurements are equal.

Once you have squared the building, cut a shallow notch with a saw underneath each string where it crosses the top of the batter board. This is more accurate than trying to rely on nails, which may bend or come loose. When the strings have to be removed for digging the footing ditch, they can be quickly restrung over the notches.

Article 13: BUILDING THE FOOTINGS

A footing ditch is required under slab and perimeter foundations. Construction manuals often explain how to lay out the site with batter boards, briefly mention that you should dig the footing ditch, then move on to the next step.

Footing ditches deserve more care. How deep should they be? How wide? What if your ground isn't very level? The answers to these and other questions given here are based on the Uniform Building Code, but local codes may vary, so be sure to check with your local inspector before starting a project. Additionally, if an architect drew up your plans, make the ditch according to the plan's specifications, which should meet or exceed local code requirements.

A footing ditch must be dug in undisturbed soil, not fill dirt. It must be deep enough to reach below the frost line. If you live in an area where the ground does not freeze, the required footing depth is 12 inches for a one-story house and 18 inches for a two-story house.

Perimeter foundation footings must be 12 inches wide for a one-story house and 15 inches wide for a two-story house. One-story houses require a 6 inch wide foundation wall; two-story houses require 8 inch wide walls. The footing must be 6 inches thick for a one-story house and 7 inches thick for a two-story house.

The footing ditch around the perimeter of a slab must be 12 inches deep or below the frost line, and 6 inches wide.

Into all footing ditches must be placed 1/2 inch reinforcing ford, know in the trade as rerod, rebar or steel. For details on how to hang steel in a foundation, see page 87.

Digging the Footing Ditch

For all the care you have put into getting the strings placed accurately, the footing ditches are not dug with great accuracy. Work carefully, but the footing may still end up a few inches out of line. However, the foundations wall itself must be placed with great accuracy. With the perimeter strings in place, mark where the footing ditches will be dug.

If a backhoe is digging the footing ditches, you need only mark the outside edge of the footing ditch. The line is marked by dribbling lime or flour from a coffee can. The operator will follow that line with the backhoe bucket. After marking the ditch, remove all the strings so the backhoe can get in there. You can replace the perimeter strings exactly as they were because the saw marks still mark the string locations on the batter board crosspieces.

If you are digging the footing ditch by hand, stretch temporary strings on the batter boards, marking the inside and outside of the footing ditch. For a 6 inch wide foundation wall, the outside of the footing will be 3 inches outside the perimeter string and the inside of the footing will be 9 inches inside the perimeter string. Use a plumb bob to transfer the string lines accurately to the ground, then mark the ditch outline.

Uneven Ground

Constructing footings for houses on steep slopes is beyond the scope of this book, but it is not uncommon to build a house or cabin on uneven ground. This may mean, for example, that the foundation wall at the high point of ground will be the minimum 16 1/2 inches above the grade, but the other end will be 3 feet high. That means pouring a lot of concrete. If practical the best solution is to have a bulldozer level the ground for you. The alternative is to step the foundation down. Short stud walls are then built on each foundation step to bring everything up to level.

SECTION V: FORMING FOR PLACEMENT

Pages 68 - 71 Article 14: *Constructing the Forms*

Pages 72 - 79 Article 15 : *Formwork*

Trainee Section Objectives

1. To become aware of basic forming techniques and hardware.
2. To competently name and describe the basic parts of common forming systems.
3. To demonstrate proper forming practices in field exercises.

Article 14: Constructing the Forms

As with any major foundation, first lay out the site with stakes and twine to roughly position the building, then construct your batter boards and place the perimeter strings. Batter boards for a slab should be built fairly low to the ground so that the string lines will be only a few inches above the top of the form boards. If you are going to have a backhoe dig the footing ditch, place chalk lines on the ground and remove the strings for the backhoe. If you are going to dig the footing ditch yourself, it can be done after the form boards are in place.

Form Boards

Usually the ground for your slab will not be perfectly level, but this is not a serious problem. The low spots can be filled in with gravel and additional concrete. Start placing the form boards at the highest corner and work toward the low corner. Using a plumb bob, drop a line from where the strings cross at the corner and place the first form board there, with the inside face just under the string. Drive a stake along the outside of the board, and nail the stake to the form board. Place a level on the form board and stake it at the other end. Continue around the perimeter in this fashion, then begin straightening and bracing the form boards.

Figure 5-1
Formwork with stakes nailed to formboards and formboards in line with stringlines.

Figure 5-2
Formwork is leveled using a building laser level.

Sight down a form board to see if it bows in or out. Pull it into line under the string and stake it. Drive stakes every 18 inches along the forms to keep them from bowing out under the weight of the concrete.

At the low side of the slab forms, there may be a gap of a few inches to nearly a foot under the top form board. Fill this gap with additional boards nailed to the stake, then pile dirt against the outside of the forms.

Footing Ditch

With the forms in place, dig the footing ditch according to your local code requirements. After the ditch is completed, hang the steel. With that job complete, you are ready to construct screed guides (for large slabs).

Screed Guides

Slabs are often 20 or more feet wide, which means you cannot find a board long enough to use as a screed when striking off the concrete. There are two ways to solve this problem. The first is to install permanent dividers in the slab, using either treated or naturally rot-resistant wood. The second solution is to install temporary screed guides that can be used both to level the gravel base for the slab and to strike off the slab itself.

Screed guides are 2 by 4's supported on stakes. Permanent guides must be level with the tops of the forms and, if more than one is used, you must space them equally apart.

Figure 5-3
Digging a footing ditch.

The guides should be 8 feet to 10 feet apart, depending on the width of the slab. For a slab 24 feet by 24 feet, for example, place the two screed guides at the 8-foot and 16-foot marks. For temporary screed guides, place one end of the 2 by 4 screed guide on top of the form, level it, and stake it in place. Now, working from the other side, repeat this process so the guides meet at or near the center.

With the screed guides in place, you will need a screed made from 2 by 4's. For temporary guides, nail an "ear" made from a 1 by 2 stake to the end of the screed that will ride on the temporary guide. The other end of the screed rides on top of the exterior form. For center screeds, use ears on both ends of the screed. Temporary screed guides will be removed after the concrete is poured.

Gravel
Add the gravel once all the items above are in place. To level the gravel inside the forms, use a screed made from two 2 by 4's held together with plywood cleats. Screeding the gravel the depth of the additional 2 by 4 places the gravel 4 inches below the top of the forms, which is the standard thickness of a garage slab. For thicker slabs, adjust the screed boards accordingly.

Vapor Barriers
A vapor barrier provides protection against water working its way through the concrete slab and helps the concrete cure better. The barrier is made by spreading 5-mil plastic sheets over the leveled gravel. Overlap the sheets by 12 inches. Do your best not to tear the plastic.

Reinforcing Wire
Reinforcing wire is sold in rolls, and you must cut it to fit within your forms. Leave it long enough to reach from form to form, and wire it to the steel in the foundation ditch. Whenever one strip of wire meets another, they should overlap by 6 inches.

The wire should be raised off the ground so it will be in the center of the slab. Place rocks at regular intervals to raise it or raise the wire during the placement using hooks. Be careful that the wire doesn't bow up so that it would be exposed on the surface.

Hanging the Steel
Steel reinforcing rods must be placed in the footing ditch in two layers, one about 2 inches from the ground and the other about 2 inches below the surface of the finished slab. Where two reinforcing rods meet, they must overlap by 24 inches for 1/2-inch diameter rerod and 30 inches for 3/8-inch rerod. Normally, 1/2-inch rerod is all that is needed in slab foundations. Use tie wire to wire the steel together. To bend the steel to go around a corner, just put one foot where you want the bend to be, then pull up on the remaining length of rod.

FORMWORK
Forms for drives, walks, and patios may be lumber or metal, braced by wood or steel stakes driven into the ground. All forms should be straight, free from warping, and of sufficient strength to resist concrete pressure without bulging. Stake and brace the

Figure 5-4
2 x 4 screed guide used to fine grade large slab.

Figure 5-5
Vapor barrier and reinforcing wire being placed for floors.

forms firmly to keep them in horizontal and vertical alignment. Setting forms to proper line and grade is normally accomplished by use of string line.

Materials

For a 4-in-thick slab, 1x4 or 2x4 lumber may be used. A 5-in. slab can be formed with 2x4's, but 2x6's are preferable. Slabs of 6-in. thickness require at least 2x6 forms. Lumber used for formwork is generally "dressed," that is, surfaced in a planing machine to attain smoothness and uniformity of size. Dressing reduces the size of lumber; consequently, the 4-in. dimension of a nominal 1x4 or 2x4 is actually 3 1/2 to 3 9/16 in., and the 6-in. dimension of a 2x6 will be between 5 1/2 and 5 5/8 in. Accordingly, the final grade should be slightly lower than the bottom of the form when using dressed 1x4 or 2x4 forms for 4-in. slabs. The same applies when using 2x4's for 5-in. slabs and 2x6's for 6-in. slabs. A little backfilling outside the forms will prevent the concrete from running under them.

On large-volume work such as public walks and housing projects, metal forms may be less expensive than wood because they permit the work to proceed faster; they can be reused more often; and they may also produce a better job. Wood stakes are made from 1x2, 1x4, 2x2, or 2x4 lumber. They may be hand cut or purchased precut. Space stakes at 4-ft. intervals for 2-in. thick formwork. With 1-in. lumber, space the stakes more closely to prevent bulging. A maximum interval of 2 to 3 ft. is suggested.

Reusable steel stakes for use with wood forms are available in various lengths and styles. They have closely spaced nailing holes and are easier to drive and pull than wood stakes. With many reuses, steel stakes can bring substantial economies for volume work. For ease in placing and finishing concrete, drive all stakes slightly below the top of the forms. Wood stakes can be sawed off flush. All stakes must be driven straight and true if forms are to be plumb. For easy stripping, use double-headed nails driven through the stake into the form and not vice versa.

Forming Curves

Horizontal curves may be formed with 1-in. lumber, 1/4-to 1/2-in. thick plywood, hardboard, or sheet metal. Short-radius curves are easily obtained by bending plywood with the grain vertical. Two-inch thick wood forms may be bent to gentle horizontal curves during staking or to shorter-radius curves during staking or to shorter-radius curves by saw kerfing. Wet lumber is easier to bend than dry lumber. Gentle vertical curves can sometimes be formed by bending a 2x4 during staking. When the change in slope is sharper, short lengths of forming may be used. The curve is laid out with a string line tied to temporary stakes. The line is adjusted up or down on the stakes to give a smooth curve; then short lengths of forming are set to the string line and securely staked. Vertical curves may also be formed by saw kerfing.

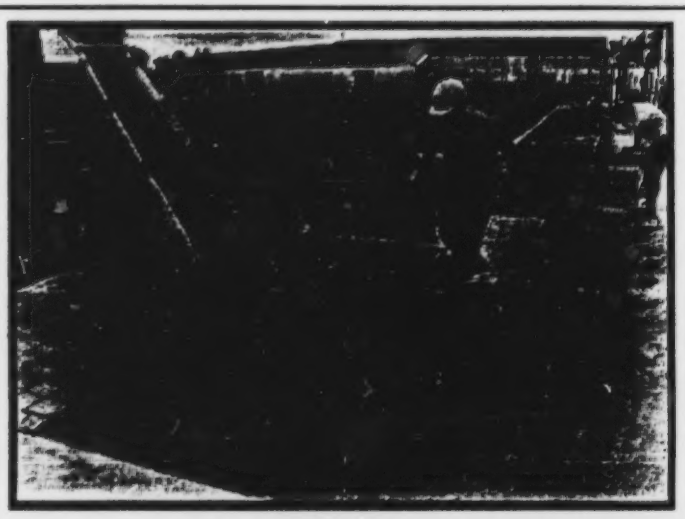


Figure 5-6
Worker raising reinforcing wire during concrete placements.

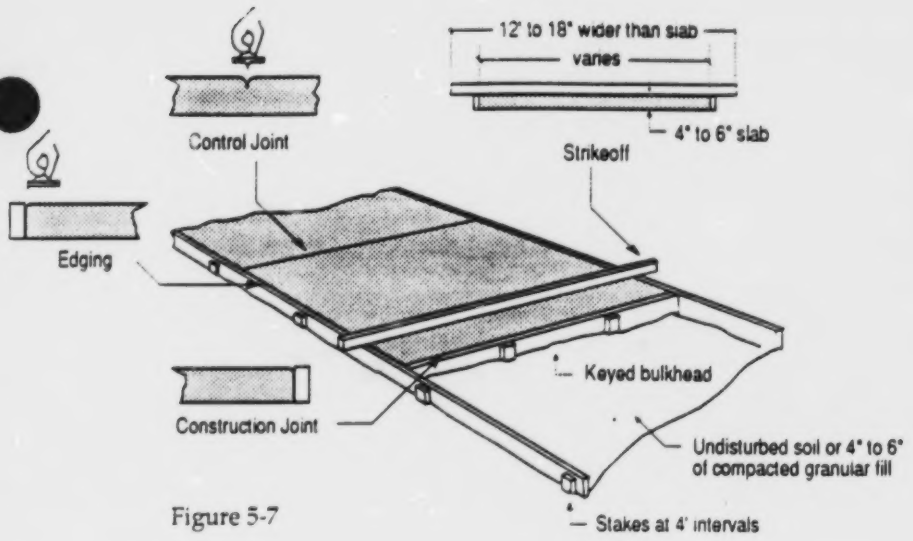


Figure 5-7

forms with water or oil them for easier form removal. Motor oil may be used for small jobs. A regular form release agent applied by hand-spray equipment is preferred for volume work.

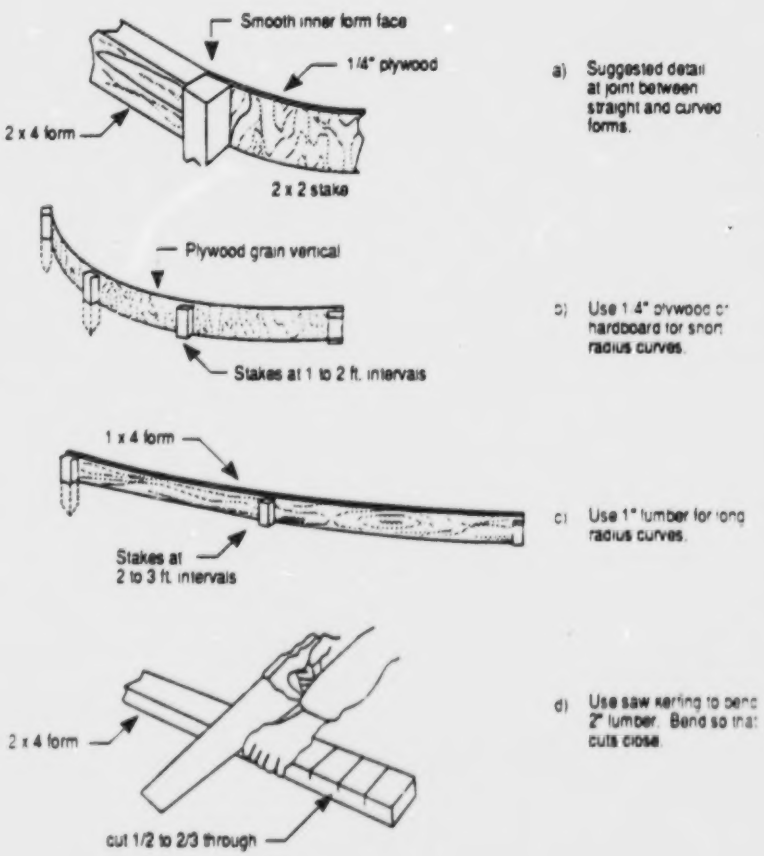
To hold forms at proper grade and curvature, set stakes closer on vertical and horizontal curves than on straight runs.

Permanent Forms

Wood side forms and divider strips may be left in place permanently for decorative purposes and to serve as control joints. Such forms are usually made of 1x4 or 2x4 redwood, cypress, or cedar that has been primed with a clear wood sealer. It is a good practice to mask the top surfaces with tape to protect them from abrasion and staining by concrete. Miter corner joints neatly and joint intersecting strips with neat butt joints. Anchor outside forms to the concrete with 16-penny galvanized nails driven at 16-in. intervals horizontally through the forms at mid-height. Interior divider strips should have nail anchors similarly spaced but driven from alternate sides of the board. Drive all nail heads flush with the forms. Never drive nails through the top of permanent forms. All stakes that are to remain in place permanently must be driven or cut off 2 in. below the surface of the concrete.

Final Check

Before concreting, give all forms a final check for trueness to grade and proper slope for drainage. Check the subgrade with a wood templet or a string line to ensure correct slab thickness and a smooth subgrade. Finally, dampen


Smooth inner form face
1/4" plywood
2 x 4 form
2 x 2 stake
Plywood grain vertical
Stakes at 1 to 2 ft. intervals
1 x 4 form
Stakes at 2 to 3 ft. intervals
2 x 4 form
cut 1/2 to 2/3 through

a) Suggested detail at joint between straight and curved forms.

b) Use 1/4" plywood or hardboard for short radius curves.

c) Use 1" lumber for long radius curves.

d) Use saw kerfing to bend 2" lumber. Bend so that cuts close.

Figure 5-8

Article 15: FORMWORK

A. Formwork Requirements

Forms are necessary to confine the fresh concrete and mold it to the required shape. The simplest form is a hole dug in the ground into which concrete is placed for a foundation or footing to support part of a structure. More elaborate forms are designed for special construction techniques. Forms, although their function is temporary, are engineered structures. They must be designed and built to impart the specified surface to the concrete in the most economical manner; to resist high loadings, both moving and stationary; to resist the hydraulic head of a heavy fluid weighing 150 pounds per cubic foot; to withstand the effects of vibration of the concrete; to confine the concrete without shifting or permitting loss of part of the concrete or mortar; and to lend themselves to rapid construction, erection, stripping and moving. Above all, the forms must be constructed with an adequate factor of safety to prevent the possibility of failure or collapse. Some common construction deficiencies that lead to form failure are:

(a) Inadequate diagonal bracing of shores
(b) Inadequate lateral and diagonal bracing and poor splicing of 'double-tier shores' or 'multiple-story shores'
(c) Failure to control rate of placing concrete vertically without regard to drop in temperature
(d) Failure to regulate properly the rate and sequence of placing concrete horizontally to avoid unbalanced loadings on the formwork
(e) Unstable soil under mudsills
(f) Failure to inspect formwork during and after concrete placement to detect abnormal deflections or other signs of imminent failure which could be corrected
(g) Insufficient nailing
(h) Failure to provide for lateral pressures on formwork
(i) Shoring not plumb and thus inducing lateral loading as well as reducing vertical load capacity
(j) Locking devices on metal shoring not locked, inoperative or missing
(k) Vibration from adjacent moving loads or load carriers
(l) Inadequately tightened or secured form ties or wedges
(m) Form damage in excavation by reason of embankment failure

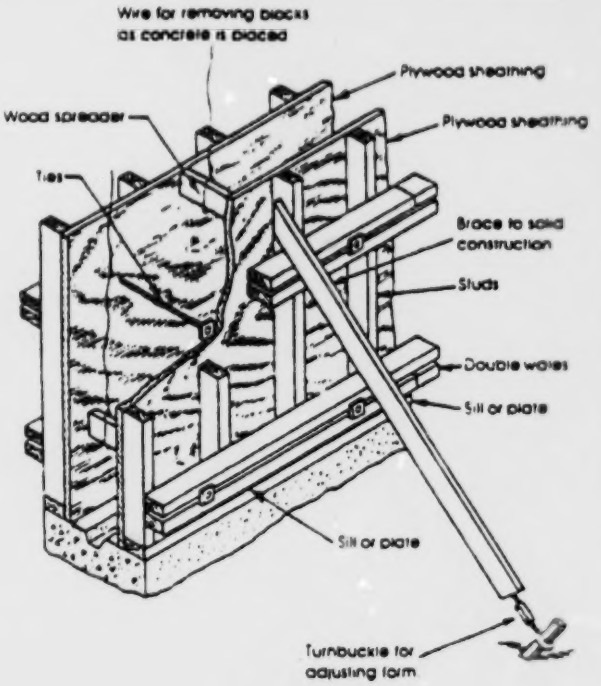


Figure 5-9
A typical job-built wall form with components identified. Wood spreaders are shown, but fequently the spreader device is part of the prefabricated metal tie.

(n) Loosening of reshores under floors below
(o) Premature removal of supports, especially under cantilevered sections

Forms are made of wood, metal, cardboard, fiberglass, plaster, plastic, concrete or combinations of two or more of these materials. By far the greatest proportion of forms are made of wood, mainly because of its general availability and ease of fabrication. A section of a simple wall form is shown in Figure 5-9 and several types of wall ties are shown in Figure 5-10.

The first consideration in designing formwork is safety. Failures of forms and shoring have resulted in many construction accidents involving injury and death to workmen and extensive property damage.

The concrete surface reflects the form surface. It is quite obvious that a smooth surface cannot result from rough formwork. Of course, there are instances when rough form lumber is used to impart a rough texture to architectural concrete, but these forms require as careful workmanship as any other.

Unsatisfactory alignment of concrete surfaces results from poorly designed forms and slipshod

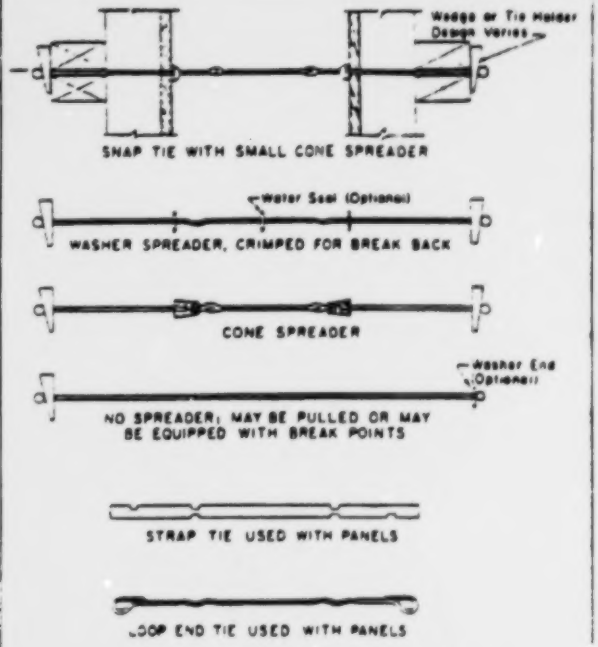

Wedge or Tie Holder Design Varies
SNAP TIE WITH SMALL CONE SPREADER
Water Seal (Optional)
WASHER SPREADER, CRIMPED FOR BREAK BACK
CONE SPREADER
Washer End (Optional)
NO SPREADER; MAY BE PULLED OR MAY BE EQUIPPED WITH BREAK POINTS
STRAP TIE USED WITH PANELS
LOOP END TIE USED WITH PANELS

Figure 5-10

Some commonly available single member ties. The holding device at the end of the tie is shown schematically since a number of different "wedges" or other devices are available. working loads vary depending on the factor of safety, kind of steel, diameter of tie, and details of the fasterner. Most of these ties are available with manufacturers' suggested working loads from 1000 to 5000 lb.

construction. Occasionally misalignment of the concrete is caused by movement of the form while the concrete is being placed and vibrated. Movement of forms during concrete placement can be prevented by attention to important details. Proper spacing of studs and walers prevents bulging; adequate fastening, bracing and wedging restrain movement of the form under pressure of the concrete while it is being vibrated; and tight joints restrict leakage of grout from the concrete.

Forms should be constructed and maintained so the finished concrete will be true to line and grade, and of the dimensions and shape shown on the plans, keeping in mind that tolerances in dimensions refer to the dimensions of the concrete in the structure, not the formwork. Forms should be constructed so they can be easily removed without injury to the workers or the green concrete. Forms should be mortar-tight, sufficiently rigid to prevent distortion caused by pressure of the concrete and other loads incidental to construction, and constructed and maintained to prevent warping and opening of the joints due to shrinkage of the form material. Molding or chamfer strips should be placed in the corners of forms to produce beveled edges on permanently exposed concrete surfaces. Interior angles on such surfaces and edges at formed joints usually do not require beveling. Chamfer strips may be job-cut strips of wood, plastic or rubber. The plans should govern relative to the use of such items.

Figure 5-11

Wall forms are held true to line and kept free of bulging and warping by the use of horizontal and vertical walers.

All lumber in contact with concrete should be free of knotholes, loose knots, cracks, splits, warps or any other defects that would mar the appearance of the finished structure. Lumber having defects affecting its strength should not be used.

Wood lining for forms should be of such kind and quality, or should be so treated or coated, that there will be no chemical deterioration or discoloration of the formed concrete surface. The type and condition of form lining and the construction of the forms should be such that form surfaces will be even and uniform. The wood or metal lining should be placed so the joint marks on the concrete surfaces will be in general alignment, both horizontally and vertically.

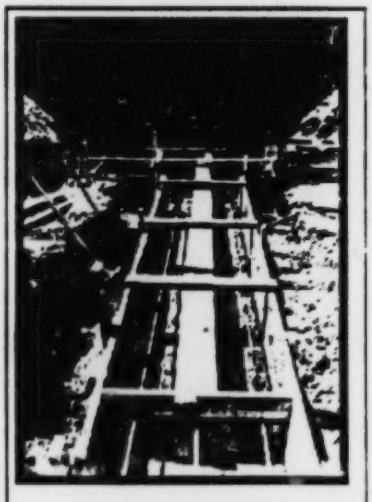


Figure 5-12

Footing forms are held true to grade with wood stakes driven alongside the forms and the formboards nailed to proper grade. Line is maintained by the use of spreaders nailed to the top of the form. The spreaders also hold up the reinforcing steel and the keyway.

Form panels, either of wood or metal, should be constructed and assembled to result in tight joints between the panels. Panel joints should match in general alignment the joints of the lining or sheathing.

Plywood sheets less than 5/8 inch or more in thickness can be used without backing, provided the forms are constructed to withstand pressure developed during placing of concrete without producing visible waviness between studs. Plywood sheets should be placed so joints are tight. Plywood placed with the long dimension horizontal (that is, across the studs) has greater strength than if placed vertically.

Metal for forms should be of such thickness that the forms will remain true to shape. All bolt and rivet heads should be countersunk. Clamps, pins or other connecting devices should hold the forms rigidly together in place and allow removal without injury to the concrete. Metal forms that do not present a smooth surface or line up properly should not be used. All metal forms should be kept free from rust, grease or other foreign matter which would discolor the concrete.

Forms should be securely tied together with rods and braced in a substantial and unyielding manner. In general, tie rods should be designed to act also as struts or spreaders. Wood struts should not be permitted to remain in the concrete.

For concrete surfaces that will be permanently exposed to view, metal ties or anchorages within the forms should terminate beneath the formed face of the concrete. The ties should be constructed so removal of the ends or end fasteners can be accomplished without causing appreciable spalling at the faces of the concrete.

Devices which, when removed, will leave an opening entirely through the concrete are usually not permitted. Wire ties may be used when both sides of the concrete will be covered with backfill or otherwise not permanently exposed. Wire ties, if used, should be cut off flush with the concrete surface.

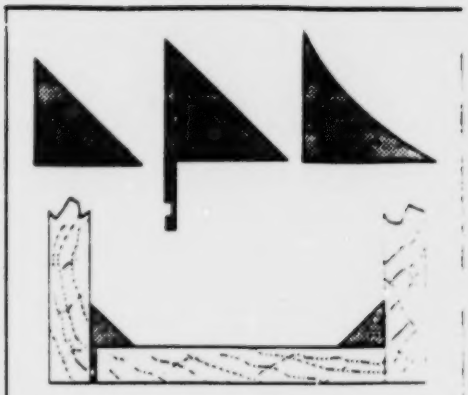


Figure 5-13

Cross-sections of some chamfer strips made of flexible polyvinylchloride are shown on top. Installation of two kinds is shown below.

In placing a successive lift of concrete on previously placed and hardened concrete, the horizontal joint between the two lifts is often a source of disfigurement. Two methods of minimizing this are shown. The gradestep shown in Figure 5-14 should be set accurately with its bottom edge about 1/2 inch below the finished elevation desired for the lift. Grooves should be straight and continuous across the structure. Their location should be planned beforehand to give a pleasing appearance to the completed structure. Form anchorages should be provided about 4 inches

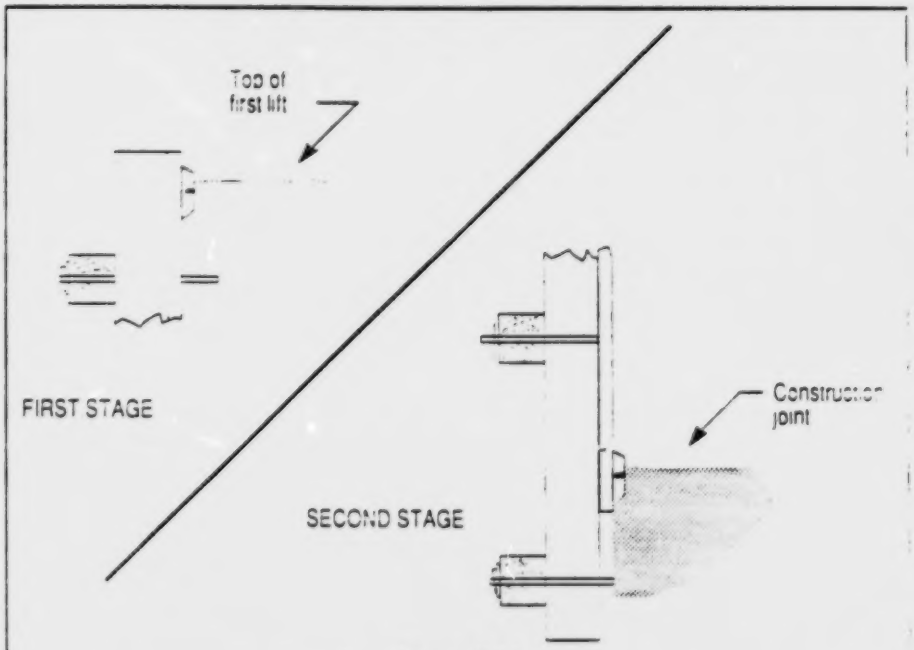


Figure 5-14

A rustication groove is formed in the concrete at the joint by the use of a trapezoidal shaped strip of wood attached to the form. The use of double-headed nails permits the form to be removed while the strip remains in place for the next lift.

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below the top of the lift. When the form is set for the succeeding lift, the sheathing should overlap the previous concrete by about 1 inch and should be drawn up snug by means of the anchorage in the concrete below and by ties close to the bottom of the new lift. Proper observance of these precautions will assure a neat-appearing joint in the structure.

Forms for suspended slabs and beams are frequently cambered to allow for sagging or settlement, a common allowance being 1/4 inch per 16 feet of span. This, however, is something that has to be considered for each individual form, depending upon many factors of form design and construction. It is good practice to install some sort of a telltale beneath a slab or beam form to check on settlement during concrete placement, and to provide information for corrective measures. A satisfactory telltale might be a vertical board suitably marked, or a ruler attached to the center of the span which can be observed by means of a surveyor s level.

Most forms must be treated with a form oil or parting compound that will prevent the form from sticking to the concrete.

Normally the choice of form materials and design of the forms is in the hands of the contractor, although there are occasions when the specifications state a requirement for a certain surface or effect on the concrete and may specify a special forming material.

B. Wood Forms

The softwoods are generally used for form lumber, the species depending on the kind that is available in the local market. The commonest kinds are douglas fir, southern pine, western hemlock and eastern spruce. Other species may be used in limited amounts in certain areas.

Lumber for forms consist of standard sizes, either rough or dressed. Because of the loadings imposed on forms, a good grade of lumber should be used; the quality known as construction grade is usually specified. Shoring or falsework should be of select grade. Partially seasoned wood, known in the trade as "shipping-dry lumber" has been found to be the most stable. Green lumber will warp and crack, while kiln dried lumber will swell excessively when it becomes wet.

Plywood is universally used for sheathing or lining forms because it gives smooth concrete surfaces that require a minimum of hand finishing, and because

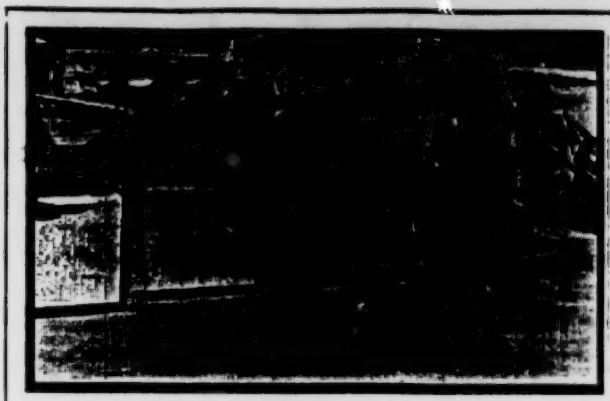

Figure 5-15
Forms being treated with form release agent to prevent concrete form sticking to the wood surface.

the relatively large sheets are easy and economical to use. Boards are sometimes used for sheathing when the architect requires the imprint of the boards on the surface of the concrete.

Plywood is a fabricated wood product consisting of an odd number of plies or layers of wood, placed crosswise of each other and glued together. The grain of alternate plies being at right angles to each other gives the plywood strength in both directions as well as minimum warping and splitting. Plywood is furnished in either interior or exterior type, with the exterior type preferred for forms because it is made with waterproof glue. Standard sizes of plywood are 48 inches wide with various lengths, a 96-inch length being common. Thickness ranges from 3/16 inch to 1 1/8 inches. Three plies comprise the thin plywood, with more plies (always an odd number) in the thicker boards. Plywood for concrete forms is usually factory treated with a form oil or parting compound. With proper care, plywood can be reused many times.

Coated plywood is frequently used. Called overlaid or plastic coated, it is ordinary exterior plywood with resin-impregnated fiber facing material fused on one or both sides. The overlay hides the grain of wood, resulting in a very smooth surface. Overlaid plywood can be used without a form oil, but a light application before each use will be beneficial in lengthening it's useful life. More than 100 reuses are commonly realized. Two grades are available, high density and medium density, the difference being in the density of the surfacing material.

Hardboard or fiberboard is made of wood particles that have been impregnated, pressed and baked. When used as a form liner, hardboard must be

backed with sheathing of some kind, as it does not have the strength that plywood has. Tempered hardboard, which is preferred for formwork, has been impregnated with drying oil or other material that makes the board less absorbent and improves its strength.

C. *Other Forming Materials*

Fiberglass - the material popularly known as fiberglass is finding increasing usage as a forming material. Correctly known as glass fiber reinforced plastic, it is especially suitable for repetitive production of complicated shapes, particularly precast elements. The initial cost of the mock-up is high, but the cost can be spread over many production units. Some users in precasting plants have reported over 200 uses of one mold with practically no evidence of wear.

The first step in making a fiberglass mold is to make a mock-up or master pattern in exactly the configuration of the finished concrete member. The master pattern can be of wood, plaster or any material that lends itself to the design to be achieved. After coating the master pattern with a bond-breaking wax, layers of polyester resin and glass fabric are applied until the required thickness is reached. Suitable reinforcement and backing must be provided so the mold will not be deformed when it is handled. Any number of molds can be made from one master pattern, depending on the requirements of the job. Molds can be used either with or without form oil. Wear of the mold surface will be slightly less if an oil is used.

Plastic and Rubber Liners - materials of this nature are those that come in the form of sheets, either flexible or rigid, to be attached to the solid form sheathing. Many patterns are available in "off the shelf" materials such as rubber floor mats. Repetitive use, a great variety of textures, and ease of stripping are among the advantages of such material. Thin flexible sheets are apt to sag and wrinkle when applied to vertical surfaces. Normally no form oil is required.

Specially formed soft rubber molds can be made for casting small wall units or tiles, statuary, and imitation stone or brick facing. These molds are used in central casting plants, where the mold can be oriented in whatever position is best for casting the objects regardless of the position the objects will take in the finished structure. For example, wall tiles can be cast in a horizontal position.

Rigid plastic sheets, such as polyurethane insulating panels, can be carved into various designs and used as a single-use liner for forms.

Steel - fabricated and rolled steel shapes are used as supporting members on forms, especially where many reuses are experienced, and for load conditions in which it is impractical to use timber. Light pressed steel shapes are used in constructing prefabricated forms which may be lined with sheet steel, plywood or hardboard. Pressed steel pans and domes, placed with steel or timber supports form the underside of waffle slabs and pan joists. Corrugated steel sheets serve as permanent bottom forms for decks; that is, they remain in place after the concrete has been placed. Smooth sheet steel can be used for facing forms, and fabricated steel forms are extensively used in the precast and prestressed concrete industries.

Paper and Cardboard - multiple layers of heavy paper are bonded together and impregnated with waxes and resins to become a water-repellent cardboard, usually found in the shape of cylindrical single-use molds for columns. Thickness may be as much as 1/2 inch. Void formers and forms for pan joists and waffle slabs are composed of heavy corrugated paper similar to the material used in boxes and cartons.

Molds - complicated and ornamental surfaces can be cast in plaster waste molds. A waste mold is made of casting plaster reinforced with fiber and supported on a wood framework. The plaster can be either cast against a master mold, or carved. Carving should be done while the plaster is still moist from the constituent in the coating temporarily prevents hydration of a very thin layer of cement adjacent to the form, thus preventing adhesion. After the form has been stripped, further curing of the concrete permits the surface to harden.

D. *Falsework and Shoring*

Some structures require support for the formwork and green concrete other than the actual forms themselves. Such a temporary supporting structure is called falsework, shoring or centering. It may consist merely of a few simple post shores, or it may be a complicated engineered structure supporting the forms for an arch or dome.

Vertical shoring under a beam or slab form can be one of two kinds:

Permanent shores, in which the form and shoring are designed so the post shores will be undisturbed when the forms are stripped. This usually means leaving a small strip or section of form in place directly over each post until the post is removed after the concrete attains the required strength.

Reshores, in which the form and post shores are removed simultaneously, each post individually being immediately replaced by a new post wedged in place to support the concrete.

Falsework should be designed and built to carry the full load of the forms, including walkways and platforms, the weight of the fresh concrete (assumed to weigh 150 lbs. per cubic foot for normal concrete), and an additional live load caused by the workmen and construction equipment.

The foundation for shoring is of great importance, since settlement must be minimized. In some cases, such as centering for an arch bridge, the falsework can be supported on piling. Mud sills are usually acceptable if they are of adequate area and are carefully placed on firm earth. Supports should never be placed on frozen or unstable ground. In a multiple-story building, supports for successive floors should be placed directly over those below. Frequently, the use of jacks or wedges is required to take up any settlement in the falsework, either before or during concrete placement.

There are several kinds of fabricated shoring components made up of wood or metal posts, jacks, adjusting devices, horizontal shores or adjustable beams, scaffold shores and joists, all of which offer a wide range of products to fit almost any form-support condition.

External bracing is required on some forms for architectural concrete when the presence of patches or plugs remaining on the surface of the concrete, as a result of using through-the-form spreaders and ties, is unacceptable.

E. Slipforms

A slipform, or sliding form, is a movable form that is raised vertically as the concrete is placed. A form of this kind is called a vertical slipform and is used on buildings and silos. Horizonal slipforms are used for highway pavements, curb and gutter, and canal linings.

F. Precast Concrete Forms

In this category we find precast wall panels, precast deck slabs, precast column enclosures and other items made of precast concrete. These units are usually of special architectural design that are more easily made in a casting yard where the finish can be achieved under closer control than on the job. After they have been cured, they are set in place on the structure and back-up structural concrete is placed. The precast unit thus serves as a form that confines the fresh concrete, then remains in place and becomes a permanent part of the building.

It is essential, of course, that the fresh concrete bonds to the precast form. Bonding is accomplished by grooving or roughening the back side of the precast unit. Grooving or roughening can be achieved by the proper selection of the form liner, or can be done with cutting tools, sandblasting or acid etching. Bond can also be made by means of metal anchors. One end of the anchor is embedded in the precast concrete, and the other end is embedded in the cast-in-place backup concrete. Usual construction provides a combination of both methods.

G. Prefabricated Forms

Prefabricated forms, made by several manufacturers, can be divided into two groups. First are the modular forms that can be used for many applications. The user adapts his formwork to make use of the modular dimensions of standard off-the-shelf form units. The second group of prefabricated forms consist of those units that are manufactured for one certain job. Dimensions of the units are based on job requirements. Prefabricated forms are frequently rented by the contractor.

A form unit usually consists of a plywood, hardboard or sheet steel replaceable panel that is held in a frame of light pressed steel shapes. Patented locking devices join the units together and spacer-ties are included as part of the package.

Some units are self-supporting, and can be joined together and stacked to form large areas. Others require studs or walers to support them.

Column forms are made of sheet steel, cardboard or fiber board. Single-use forms are made of paperboard tubing that can be stripped by making one or two vertical cuts with a saw or special knife, then peeling the paperboard off the concrete. Sheet steel is frequently used for re-usable forms. Square

and rectangular columns can be formed with sheets of plywood held in place by special column clamps as shown in Figure 5-16.

Prefabricated forms usually require the field application of some sort of form oil, except the paperboard tubes which are factory treated with a parting compound.

H. Use of Forms

Dimensions of forms in place should be carefully checked before concrete is placed. Immediately prior to placing concrete, any warping or bulging should be corrected and all dirt, sawdust, shavings or other debris removed. In narrow walls, where the bottom of the forms is otherwise inaccessible, the lower boards or panels should be left loose on the back side so that extraneous material can be removed just prior to placing concrete, then the board or panel can be replaced.

Whenever it is at all possible, the inspector should get down into the forms to make his inspection. While it is true that sometimes the forms are so congested and tight that a man cannot get in, nevertheless, it is difficult to inspect a tall form from the top only.

Runways for buggies and workmen should not be laid on the reinforcing steel mat, unless special high supports are inserted under the top layer of bars to keep them from being pushed down. When using metal chairs to support the reinforcing bars on a wood or plywood bottom form, the chairs should be checked to see that they do not punch into the wood, thus lowering the steel from its intended position. Chairs are available that overcome this punching tendency.

It sometimes becomes necessary to install a construction joint with the reinforcement extending across the joint. To avoid bending and possibly damaging the steel, the bulkhead form should be split along the line of the reinforcing bars so it can be easily removed in two parts without disturbing the steel in the hardened concrete.

Figure 5-16
Special column clamps are used with plywood sheeting and 2x4 studs to form this column.

During concrete placing, it may be necessary to have form watchers to observe the forms for evidence of settling, bulging, slipping or movement of any kind. Telltale indicators are frequently used.

Anchor bolts for machinery, columns or other structural elements should be fastened in a template that will accurately and firmly hold the bolts in correct position while concrete is being placed.

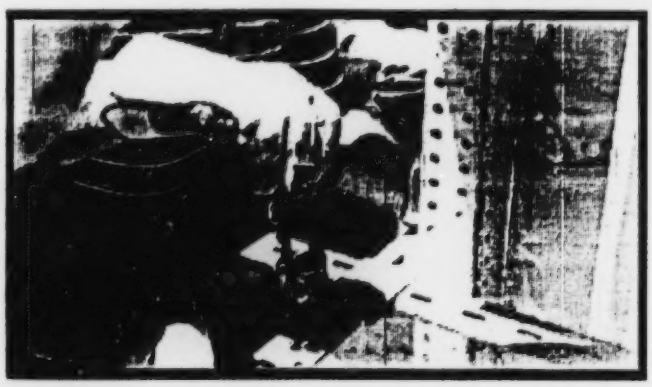

Figure 5-17
Locking device for steel form column clamps.

I. Removal of Forms and Shoring

The care exercised in handling and using a form will be reflected in the serviceability of that form. With few exceptions forms are designed and built for reuse. This is particularly true of prefabricated forms. Single use job built forms are built of components that can be reused. Plywood can be used several times; coated plywoods can be used many times. Timber for studs, walers, shoring and other structural parts of the form can be salvaged and reused. When the forms are carefully stripped (removed from the concrete) not only is the concrete surface undamaged, but the form itself is preserved for additional use. After a form has been

stripped, it should first have all dirt and mortar removed, then it is coated with an appropriate parting compound. Metal scrapers and wire brushes should be used with care, as they can scratch and roughen plywood, and overuse on steel is apt to clean the steel down to bright metal, which is undesirable. A small block of wood makes a good scraper. During removal and cleaning of forms, buckets or other containers should be handy to receive the many items of small hardware that are reusable. Solvents are available for cleaning these items. If the forms are not to be reset immediately they should be carefully stacked to prevent warping.

The length of time that forms and falsework must be left in place depends on the type of structural element under consideration and the strength development of the concrete. Vertical side forms on walls, beams and columns can usually be removed on the day following placing of the concrete. It may be necessary to retain shoring under slabs and beams for three weeks or even longer. Normally the specifications are quite explicit on the strength required of the concrete before support can be removed. In this connection, the Uniform Building Code reads as follows:

"Sec.2606. (b) Removal of Forms and Shores. No construction loads exceeding the dead load plus live load shall be supported on any unshored portion of the structure under construction. No construction loads shall be supported on, nor any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with the remaining forming and shoring system has sufficient strength to support safely its weight and the loads placed thereon. This strength may be demonstrated by job-cured test specimens and by a structural analysis considering the proposed loads in relation to these test strengths and the strength of the forming and shoring system. Such analysis and test data shall be furnished by the contractor to the Building Official when so required."

"Forms shall be removed in such manner as to insure the complete safety of the structure. Where the structure as a whole is adequately supported on shores, the removable floor forms, beams and girder sides, column forms, and similar vertical forms may be removed after 24 hours, provided the concrete is sufficiently strong not to be injured thereby."

SECTION VI: PLACEMENT AND CONSOLIDATION

Pages 81 - 84	Questions on film: *Transporting and Placing Quality Concrete*
Pages 85 - 86	Questions on film: *Concrete Vibration*
Pages 87 - 89	Article 16: *Materials in Concrete*
Pages 90 - 100	Article 17: *Conveying, Placing and Consolidating Concrete*
Pages 101 - 103	Article 18: *Concrete Vibration*

Trainee Section Objectives

1. To learn the basic types of Portland Cement and their uses.
2. To become aware of the proper procedures of concrete placement and consolidation.
3. To demonstrate competency in placing and consolidating concrete

"Transporting and Placing Quality Concrete"

Questions on information in the Portland Cement Association film

1. How does the film define the following terms:

   a. Water to cement ratio

   b. Slump

   c. Air content

   d. Uniformity

   e. Consolidation

   f. Specification

2. How is the term segregation defined?

3. What happens when a bucket containing concrete is jarred?

4. What distances does the film say concrete has been effectively pumped?

5. Why does pumping resist segregation?

6. What does the film say about kinks and bends in pump hose?

7. What criteria govern aggregate and slump when pumping concrete?

8. What does the film recommend in placing concrete in walls, beams, and girders?

9. What equipment is used to control segregation when placing concrete in walls?

10. How does the film define the vibration process?

11. What are the 5 points the film makes about forms?

12. What rules does the film have for the placement process for slabs? For a slope?

13. When does strike off occur? What does strike off accomplish?

14. How does the film say a vibrator should be lowered into concrete?

15. Should concrete be moved with a vibrator? ..... Why not?

16. What does the film say about slump and vibration?

17. What is the rule on vibration of lifts?

18. What does the film say vibration does to voids?

19. What happens when the vibrator is held too long in one place?

20. When does the film say to stop vibrating?

21. What is the most effective coolant in the hot weather concrete process?

22. What other means are used to control the temperature of concrete prior to delivery at job site?

23. What is another way to control the set of concrete in hot weather?

24. What is the critical temperature point in cold weather placement of concrete?

25. How are materials heated for cold weather concreting?

26. What temperature does the concrete need not exceed at job site?

27. What is the temperature range that heating of aggregates and water should heat the concrete to when it is ready to be delivered?

28. What does the film say about ice and snow in forms?

29. When is freezing of the concrete a danger?

30. Which of the processes: delivery, placement, consolidation, finishing, can be slowed down in cold weather?

"Concrete Vibration"

Questions on information in the Laborers-AGC film

1. Which safety factors does the film discuss?

2. How does this film define segregation?

3. What freefall distance does the film recommend?

4. What are the recommended lifts?

5. How much does the film say to penetrate lifts with the vibrator? Why?

6. What are the signs to determine effective vibration?

7. a. What is meant by "Fields of Action"?

   b. How are they overlapped?

8. What is the distance recommended for immersion points?

9. Why do you slowly withdraw the vibrator in low slump mixes?

10. What is the time recommended for vibration?

11. How is the vibrator held?

12. What does the concrete do to the vibrator?

13. Why is it recommended to stay away from the forms with the vibrator?

14. What is the "Rule of Thumb" about vibrating more or less?

15. What is important to observe about the forms when vibrating concrete?

16. How should concrete be placed in a deck pour?

17. How is segregation prevented in a wall pour?

18. What is the recommended procedure in vibrating concrete in beams or walls?

Article 17: Materials in Concrete

Kaiser Cement Technical Service Department

Bulletin 1.

By Kaiser Cement

When you purchase ready-mixed concrete from a supplier, you are not buying a finished building product. It is you, the user or consumer, who gives this plastic material its final form. Quality is largely determined by the manner of usage and proper observance of recognized and approved methods of placement, finishing and curing. Therefore, a basic understanding of the components that make up a quality concrete is necessary to produce desired workability in the fresh concrete, and required qualities in the hardened concrete.

In general, the ready-mix supplier is responsible for quality of all ingredients or component materials that go into the concrete mix. Proportions for concrete and selection of materials are based on the most economical use of available materials which will produce a concrete of required workability, placeability, durability and strength. Specification is a matter for the informed. Professional advice should be employed whenever possible.

Quality of concrete depends not only upon the quality of materials used, but on the quality of workmanship, and procedures of utilizations.

Concrete is composed essentially of three materials, cement, water, aggregates. A fourth material, an admixture, is often added for a variety of specific purposes, such as entrainment of air, acceleration or retardation of setting and hardening, etc. A brief discussion of each of these materials follows:

Cement

Normally, about 10 to 15% of the total volume of a concrete consists of hydraulic cement. This ingredient, in respect to volume, is the lesser of all ingredients. Nevertheless, it is the most important. Combined with water, a paste is formed. This paste is the cementing medium which binds aggregate particles into a solid mass. Quality of concrete is greatly dependant and governed by quality of the paste. Strength and durability, the two principal requirements of a hardened concrete, depend upon the paste for those properties. Paste covers the surface of all pieces of aggregate particles, hardening into a solid homogeneous mass.

Special types of cement are available for use in concrete to help meet every job condition and requirement. For general construction purposes, there is little need to be concerned with the different types of cements. However, in addition to standard portland cement for general construction purposes, special types of portland cements are available for special or specific uses where special properties are required, Normal portland cement, Type I, is furnished when type of cement is not specified.

Different types of cements normally available are as follows:

Types of Cement

Portland Cements - The five basic types of portland cement are:

Type I	Standard portland cement for use in general construction. A standard type for use when special properties of other types are not required. Ready mix concrete usually is proportioned with Type I Cement, unless another type is specified.
Type II	Modified portland cement for use in general concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required. Used in large piers, heavy abutments, heavy retaining walls, or other mass structures of considerable size where moderate heat of hydration will tend to minimize temperature rise. Moderate sulfate resistance property gives protection against sulfate attack where sulfate concentrations are higher than normal, but not unusually severe.
Type III	High early strength portland cement for use where high strengths are required at an earlier age. Used where it is necessary to remove forms as soon as possible, or to place the concrete in service at an early date. In cold weather, reduces the necessary period of protection. Most important character is rapid rate of strength development.
Type IV	High sulfate resistant portland cement for use when a low heat of hydration is required. Used where the amount and

rate of heat generation must be kept to a minimum. Not suited for general concrete construction. Usually available only on special order.

Type V — High sulfate resistant portland cement used in concrete exposed to sever sulfate actions.

Air-Entrained Portland Cements

Types I, II, and III portland cements are covered in air-entrained types by A.S.T.M. Specifications. These types are identified by the letter "A" following the type number, such as IA, IIA, or IIIA.

Special Types

Plastic Cements - Portland cements containing plasticizing additives, which give special property performance required for stucco and plaster construction, either interior or exterior, produce mortars that are more plastic and cohesive than portland cement.

Masonry Cement - Masonry cement is a hydraulic cement produced by inter-grinding portland cement clinker, limestone and gypsum. Plasticizing and air-entraining agents are usually added during finish grinding to provide necessary water retention and cohesiveness in the mortar, as well as to improve workability and plasticity.

Oil Well Cement - Oil well cement is portland cement standard or modified, suitable for use in cementing oil or gas wells. Because of the unusual environmental use, physical properties of the cement differ from those of A.S.T.M. C150 for portland cement. Chemical and physical properties for oil well cement are designated and specified by the American Petroleum Institute (API). Special retarders are used with the cement to delay thickening time, and extend pumpability of cement slurry pumped to bottom hole environments of elevated temperatures and pressures.

Blended Cements - Some natural pozzolans, granulated blest furnace slags and fly ash have hydraulic cementitious properties when they react with the calcium hydroxide produced during the hydration of portland cement. These blended cements meet ASTM C 595 specifications, and when used in concrete usually show lower permeability, lower heat of hydration and reduced alkali-aggregate expansion. Because of the lower permeability there is improved resistance to sulfate attack, Type IP cements are generally available in the western United States and those designated MS (moderate sulfate resisting) have excellent sulfate resistance.

Aggregate

Concrete aggregates may be either normal weight, lightweight or heavyweight types. All three types can be utilized in the production of structural concrete, In addition, some lightweight aggregates, as covered by A.S.T.M. C 332, are utilized in concrete in which prime consideration is the thermal insulating property of low density concrete. Properties of aggregates can generally be divided into two broad classifications. These are natural properties established by the character of the material that remains unchanged in processing, and manufactured properties that result from mining and/or processing. Unit weight of concrete can be achieved over a wide range of 15 pounds per cubic foot to about 270 pounds per cubic foot through selection of a specific type of aggregate.

Whereas cement is the most expensive ingredient of concrete, aggregates represent the largest volume. Normally, 66 to 78% of concrete is made up of aggregates. This bulk and relatively inexpensive unit cost are responsible for making concrete an economical, competitive building material. For most concrete the selection of aggregates is limited to the types available locally. Aggregates also must meet specific specification requirements. This is the responsibility of the ready mix dealer. Particle shape and gradation, and maximum size, have a significant influence on both the proportions and economy of the concrete, as well as ultimate quality. Aggregates must consist of clean, hard, strong and durable particles, free of chemicals or coatings of clay or other fine materials. Weak friable particles are undesirable.

Two classifications of aggregates are utilized in the production of concrete. These are designated, Fine Aggregate and Coarse Aggregate.

a. Fine Aggregate - Consists of natural sand, manufactured sand, or a combination thereof, graded in size from 1/4" maximum diameter to near dust size, (+200 mesh sieve).

b. Coarse Aggregate - Consists of crushed stone, gravel, blast-furnace slag or other approved similar materials, well graded in respect to size, in conformance with specifications.

Concrete is scientifically designed to make the most economical use of a combination of fine and coarse aggregates to produce desired quality concrete. The design is based on actual laboratory physical tests of the aggregates and concrete.

Proper grading of aggregates is important. To insure dense stacking, or near solid arrangement of particles in place, aggregate must be suitably graded from coarse to fine. Favorable grading of aggregate serves the two important functions of (1) contributing to the workability and uniformity of the concrete and, (2) reducing the quantity of cement paste required to produce concrete of quality. For most construction, coarse aggregate is all below 1 1/2" in size. For economy and quality, specify the largest size course aggregate practical to use for conditions of the job. Generally the larger the maximum size of the coarse aggregate, the less water and cement is required to produce quality concrete. Maximum size will depend on the size and shape of the concrete members and amount and distribution of reinforcing steel, if any. This should not exceed 1/5 of the minimum dimension of the member, nor 3/4 the clear spacing between reinforcement bars.

Shape of the aggregate particles also has significance. Very sharp, rough particles or flat elongated pieces require more fine material (sand) to produce workable concrete, than aggregates rounded or cubical in shape.

Ready-mix dealers are qualified to advise on specification, quality, ratio of fine to coarse aggregate, and other matters relating to aggregates in concrete.

Water

Mixing water is perhaps the least costly ingredient in concrete, but nevertheless one of the most important. The amount of water used largely determines the ultimate strength of concrete. There is a definite relation between the amount of water used and the quality of the resulting concrete; increasing amounts of water sacrifice quality. Additional water thins or dilutes the paste, reducing the cementing action and strength of the paste. It is necessary to limit mixing water to that which will just permit proper handling and placement. Water in concrete serves a dual function. It first converts dry cement and aggregates into a plastic, workable mass, and secondly, reacts with cement chemically to hydrate and harden the plastic mass into a solid, strong unit.

The all-important relationship of water to cement is known as water-cement ratio. This is expressed as a numerical ratio of pounds of water in relation to pounds of cement per unit of concrete. In general, the lower the ratio, the denser and stronger the paste. The ratio is established either by the ready-mix producer when he supplies the concrete or by specification of the consumer when requested.

Water used in concrete must be free of acids, alkalies and oils. Particularly to be avoided is water containing decayed vegetable matter or organic materials. Generally, water which is suitable for drinking purposes is usually satisfactory for concrete.

Article 17: Conveying Concrete

After the concrete has been discharged from the truck mixer, it must then be placed in the forms. For most structures, because of long distances, difference in elevation, or obstructions that block movement of the truck, some means must be provided for moving the concrete from the mixer chute into the forms.

Conveying equipment must be selected with care. Not only must cost per cubic yard and cubic yards per hour be considered, but also the layout of the site and characteristics of the concrete to be handled. Maximum size of aggregate, slump, sand content, whether normal weight or lightweight, all must be evaluated, and equipment selected that will efficiently handle the kind of concrete specified. Essential requirements of any system of moving concrete from the mixer to the forms are to minimize segregation, prevent loss of part of the concrete, and avoid excessive loss of consistency (slump). Among the methods used are direct discharge from mixer into the forms, crane and buckets, pumps, conveyors, buggies, wheelbarrows, pneumatic placers, small rail cars, or a combination of two or more of these methods. Helicopters have been employed for transporting equipment and concrete buckets into especially isolated or difficult sites.

Figure 6-1
Direct discharge from the mixer truck is used to place concrete in this slab.

The method used depends on the size of the job, adequacy of space, availability of equipment and other factors. The job should be planned so the ready-mix trucks can get as close to the actual site as possible. Unused equipment and piles of materials should be out of the way to give the trucks more freedom to maneuver. The method and equipment used should not impose a restriction on the slump of the concrete being placed, as the slump is determined by the specifications for the structure.

Direct Discharge

Some jobs are so laid out that the ready-mix truck can discharge directly into the form or on the subgrade. Extra lengths of chute are carried on the truck that provide a placing radius of about 15 feet from the truck. This method minimizes the amount of handling of the concrete, but long extensions of the chute at a flat angle are apt to result in demands for more mix water so the concrete will flow down the chute. Such demands, of course, should be resisted as long as the concrete is at the specified slump. When the truck can move alongside a slab, the extension chutes can enable coverage of a relatively large swath as the truck moves along. The flat angle of the chute, however, makes it necessary to assist the concrete to move down the chute, unless the truck is elevated slightly above the slab, or a high-slump concrete is used.

Concrete can be discharged directly into any structural form as long as the mixer discharge is sufficiently high above the top of the form. How high depends on the kind and size of mixer and how close to the form the truck can be spotted; usually a height of about 4 feet is sufficient.

Chutes

Some sort of chuting arrangement enters into many concrete distributing systems for moving concrete to a lower level. Every truck mixer has two or three short lengths of chute that enable the truck to discharge concrete over an extended area because of the high-discharge nature of the mixer.

Chutes should be of rounded cross section, made of metal or lined with metal, smooth to prevent the concrete from sticking, and of the proper slope so concrete of the required slump will slide, not flow, fast enough to keep the chute clean but not fast enough to cause segregation. Stiff mixes require a steeper slope than wet or fluid mixes, and as long as there is no segregation or separation any reasonable slope can be tolerated. A slope of about 1:3 is about as flat as possible to use, and slopes steeper than 1:2 are apt to give trouble with segregation.

Regardless of the slope, there is always some segregation at the discharge of the chute. For this reason, end control should be provided so the concrete will drop vertically without segregation

from the end of the chute. Two or more sections of metal drop chute "elephant trunk" will serve to control end segregation. A mere baffle is not adequate. Care should be exercised to prevent water, used for flushing the chute, from entering the forms.

Buckets

Properly designed and operated, are an excellent means of conveying concrete. Capacities range from less than 1 cubic yard for structural use to 12 cubic yards for mass concrete. Each bucket should have a capacity of at least one batch of concrete as mixed, except that this requirement is waived when truck mixers are used. Buckets can be handled by cranes, derricks, trucks, rail cars, helicopters or cableways. Moving by cranes is the usual method of handling buckets in building construction.

Cylindrical, bottom-discharge buckets are used in most structural applications. Size of the bucket, depending on the capacity of hoisting or other handling equipment and the job conditions, is frequently less than 1 cubic yard but may be as high as 2 or 3 cubic yards. Buckets should have nonjamming gates, and the discharge rate should be controlled so small increments of concrete can be discharged at a time. Gates are usually manually operated except on large mass concrete buckets which have pneumatic or hydraulic controls. Lay-down buckets are frequently used in building construction, their main advantage being their low filling height which facilitates filling them from transit mixers. Best results with any bucket are obtained when the discharge gate is symmetrically located in the bottom of the bucket. Less segregation of the concrete results and there is less tendency of a suspended bucket to kick sideways when the concrete is discharged. Common practice when dumping concrete from the bucket directly into a narrow form is to attach a rubber boot or sleeve to the bottom of the bucket to direct the flow of concret (Figure 6-2).

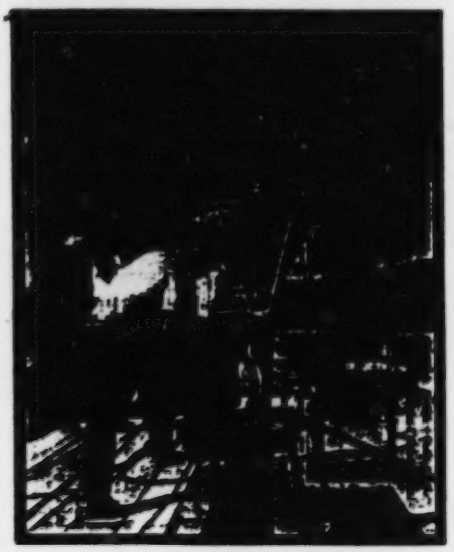

Figure 6-2
Bucket with a drop chute places concrete in a wall form.

Care should be taken to avoid shaking and jarring the concrete, as this causes segregation, especially if relatively high-slump concrete is being handled. Hauling buckets on truck or cars for a considerable distance, especially if the buckets are subject to appreciable jolting or bumping, can cause segregation. Besides the detrimental effect on the concrete itself, segregation makes it difficult to get the concrete out of the bucket.

Belt Conveyors

Concrete is frequently moved by belt conveyor. One system, consisting of a short flight of conveyor that is attached to and carried on the truck mixer, allows the ready-mix truck to place concrete as much as 12 feet above grade or any place within about 20 feet of the truck discharge spout. Other conveyor systems consist of portable conveyors, a series of conveyor flights for long-reach applications, or spreading conveyors with means of side discharge at points along the length of the conveyor. Belts can move concrete long distances horizontaliy, and to some extent vertically.

Two problems associated with belts are segregation of concrete and loss of concrete and mortar that adhere to the belt. Segregation can be controlled by the use of discharge control as discussed under "chutes", and the use of hoppers to feed the concrete onto the belt in a continuous stream or ribbon. Feed hoppers should be constructed in such a way that there are no dead areas where concrete might hang up. Loss of mortar on the return belt can be prevented by placing a rubber or other suitable scraper at the discharge end of the belt. Scraped mortar should be fed into the concrete receiving hopper. Long conveyors, or series of conveyors, should be covered when ambient conditions make it necessary to protect the concrete from rain, hot sun, wind or other unfavorable climatic conditions.

Belts are not large, a 16-inch width being common. Troughing of the belt is accomplished either by the use of troughing rolls or by a continuous pan over which the belt passes, the advantage of the pan being less segregation of the concrete. Individual flights, commonly about 50 or 60 feet long, can be joined together to permit the moving of concrete over longer distances. Transfer of concrete from one conveyor to another is accomplished by a swivel arrangement that supports the conveyor ends and guides the concrete from one belt to the next. The swivel enables the receiving conveyor to be swung through an arc to cover a large placing area, in addition, the end conveyor telescopes under the preceding flight to provide still more maneuverability. The maximum angle for elevating concrete, about 30°, is reduced when high-slump mixes are transported. Also, the belt capacity, which is usually in the range of 50 or 60 cubic yards per hour, with rates as high as 100 cubic yards per hour reported, is curtailed when wetter mixes are used. Power for operating the belt is supplied either by a gasoline engine through a hydraulic drive, or an electric motor.

Figure 6-3
Power buggies are used to move concrete to remote areas of a placement and can haul up to 1/2 ycubic yard per load.

Wheelbarrows and Buggies
Pneumatic-tired wheelbarrows can be used for moving small amounts of concrete for short distances. About 200 feet is the maximum horizontal distance for a wheelbarrow. One man with a wheelbarrow can move a maximum of about 1 1/2 cubic yards of concrete per hour.

Two-wheel buggies or carts may be either manually driven or power driven. Hand operated carts can carry about 6 or 8 cubic feet each, with a maximum haul of about 200 feet. One man and cart can move a maximum of 5 cubic yards of concrete per hour under favorable conditions. A power driven cart (Figure 6-3) has a capacity of up to 1/2 cubic yard and can move a maximum of 20 cubic yards of concrete per hour on a moderate length of haul. Maximum haul should not exceed 1000 feet.

Runways for wheel barrows and buggies should be rigid, smooth and level. They are best supported by the forms, although sometimes they may be at least partially supported on the reinforcing steel provided the steel is secured in such a way that it will not be displaced by the weight and impact of the moving carts.

Other Methods
On many jobs it has been found convenient to discharge the truck mixer into a hopper from which the concrete can be loaded into carts, buckets or other conveying equipment. It may be necessary to elevate the truck on a ramp to provide sufficient headroom. Employing a surge hopper in this manner provides some flexibility of operation and occasionally permits the truck to load without delay.

Small side-dump cars operating on portable sections of monorail track have been used for transporting concrete about the job. They are limited to horizontal, or nearly horizontal, movement. End-dump buckets transported by forklift have been used.

Hoists and elevator towers are used in high rise building construction. The ready-mix truck can discharge into the hoist bucket directly or into a receiving hopper. At the upper end the hoist bucket usually charges another hopper from which the concrete is taken by wheelbarrows or carts for distribution about the floor.

Segregation
One of the most important considerations in handling concrete, as has been pointed out several times in this article, is the avoidance of segregation, or separation of the coarse aggregate from the mortar.

Concrete is not a homogenous material, and is subject to forces attempting to separate the component materials. Separation should be prevented before it happens, rather than an attempt being made to correct it afterward. Concrete should not be dropped through reinforcing steel or other

objects that tend to separate it, nor should it be directed against the forms.

Pumping Concrete

Transporting concrete through a pipeline has been employed since the 1930's using heavy pumps that could handle concrete containing aggregate as large as 2 1/2 or 3 inches. These heavy pumps are especially useful on bridge, dam and similar heavy construction projects. In building construction great use is made of the small-line pumps.

Conditions that lend themselves especially well to pumping exist on those sites and areas where access is limited and the site is crowded with materials and equipment, such as many city building sites. Nearly all pumps, large and small, can pump vertically, thus lending themselves very well to high rise building construction. A pump takes small space, and can be located any place that the ready-mix truck can reach. Conveying hose and pipe are easily placed out of the way and take little room. In locations difficult to reach with the ready-mix truck, such as on a steep hillside, a pump can easily move the concrete over obstructions that would be exceedingly difficult for the trucks to overcome.

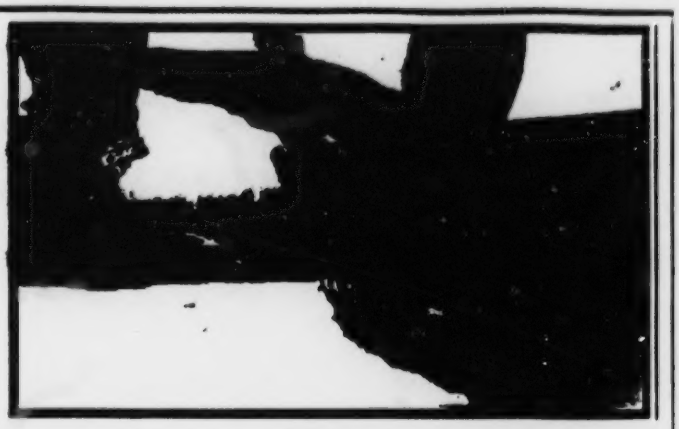

Figure 6-5
Hose connections must be tight and free of leaks. Mortar leaking from hose connections can cause plugging of the line.

Equipment

There is available a large variety of pumping equipment suitable for almost every concreting job. These pumps owe their name to the fact that the concrete is pumped through conduit 4 inches or less in diameter, this being small when compared with the 6 or 8 inch lines on the heavy pumps. Many of these rigs are small and portable enough to be mounted on a trailer that can be towed behind a pick-up truck. Others are truck-mounted. Capacities up to 90 cubic yards per hour are claimed, the actual rate depending on length of vertical lift, slump, mix proportions and maximum size of aggregate. In general these small-line pumps evolved from grout and plaster pumps. The small size pumps, being little more than mortar or plaster pumps, should not be confused with the larger sizes that can handle concrete mixes containing aggregate as large as 1 1/2 inches. There are several makes of piston pumps, either hydraulically or mechanically driven, most of them with two pistons alternating on the power stroke. The large (6 to 10 inch diameter) low velocity pistons force the concrete through reductions to the pipe or hose which may be from 2 to 4 inches in diameter. Concrete from the ready-mix truck is deposited in the holding or loading hopper leading directly to the loading chamber, passing through valves into the unloading chamber where the piston forces it into the pipe or hose for delivery to the forms.

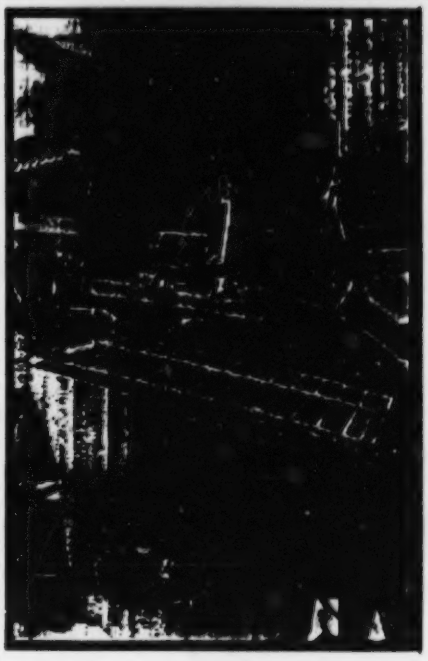

Figure 6-4
Pump hopper being charged with concrete from a mixer truck.

Another pump consists essentially of a pair of rubber rollers that squeeze the concrete out of a 3 or 4 inch diameter tube lining a drumshaped vacuum changer. There are no valves, pistons or other mechanism in direct contact with the concrete.

A third type of pump is the pneumatic type in which the concrete is carried through the pipe by air pressure in a manner similar to shotcrete, but discharge is at low velocity.

Yet another kind is the Moyno pump which consists of an auger-shaped rotor that rotates inside a

rubber-lined stator, moving the concrete in much the same way as a screw conveyor.

Delivery lines from the pumps can be either rigid pipe or hose. Pipe is usually of steel. Some usage has been made of aluminum pipe, but it has been found that a reaction between the concrete and the aluminum causes the formation of hydrogen gas which seriously reduces the strength of the concrete. For this reason aluminum pipe should not be used. Flexible conduit and hose, although they develop more resistance to pumping and for this reason should be kept at a minimum on any piping layout, provide flexibility in distributing the concrete. Rubber hose should not be inserted adjacent to the pump, especially in a long line. Change in direction is best accomplished with long radius curves rather than elbows. Minimum pumping resistance will be achieved with a maximum of straight runs of pipe, the use of pipe free from dents and encrusted concrete, a minimum use of bends and hose, and the largest practical diameter of pipe. Boom extensions are available that aid in getting the conduit over obstructions to reach the forms.

Materials

The size, shape, grading and proportions of aggregates are all important in obtaining a pumpable concrete. Some operators suggest the maximum size of coarse aggregate should be no larger than about 40 percent of the conduit diameter.

Rounded or subrounded aggregates make better mixers for pumping then aggregates containing a large proportion of crushed material, although the latter can be used satisfactorily. If it becomes necessary to use crushed rock coarse aggregate, every measure should be taken to assure maximum plasticity of the concrete as described in the section on mixers.

Grading of the aggregates should conform to the requirements of the code or specifications under which the work is being performed. Sand must contain adequate fines, with 15 to 20 percent passing the No. 50 screen and at least 3 percent passing the 100-mesh. In 1 inch or 1 1/2 inch mixes, the total aggregate should contain about 10 to 15 percent pea gravel.

Poorly graded aggregates are apt to result in concrete that is difficult to pump, the friction of such concrete in the conduit offering so much resistance that maximum pumping efficiency is not achieved. Skip or gap gradings are not suitable. Any of the usual types of portland cement can be used in concrete to be pumped.

Good construction practices govern the use of admixtures, and neither special limitations nor tolerances need to be applied so far as pumping is concerned. During hot weather a set retarder may be desirable if concrete is being pumped a long distance.

Any admixture that improves workability of the concrete will improve pumpability. Water reducers, air entrainers and fine mineral admixtures can be of advantage in the same way that they improve any concrete mixture, and their usage should be governed by the same rules and standards. Some research has been done in the use of water-soluble polymers obtained from cellulose compounds that appear to reduce friction and bleeding in the pipe system. They are not generally available at this time.

Mixes

Concrete for pumping must be plastic and workable. Because of this many persons have felt that a very high percentage of sand, as much as 65 percent of total aggregate for a 1 inch maximum aggregate concrete, is necessary. However, pumps have been improved to the point where they can handle mixes with a higher proportion of coarse aggregate and, while a slightly over sanded mix is more pumpable, other things remaining the same, excessive oversanding is not considered necessary. The

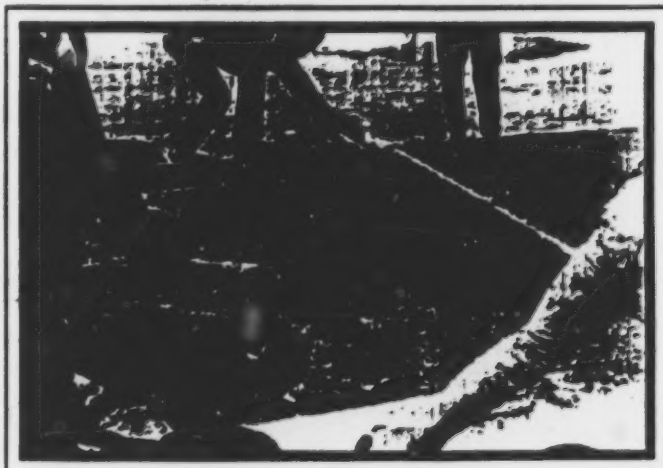

Figure 6-6

Concrete is discharged from pump hose at low velocity and is free of segregation because it is compacted in pump hose during delivery. This is 4" to 5" slump concrete.

percentage of sand in the mix should be based on the void content of the coarse aggregate, a properly proportioned mixture containing enough sand to fill the voids in the coarse aggregate and enough paste to coat the aggregate particles. If this condition is achieved, a pumpable concrete can be realized even with relatively poorly graded coarse aggregate. However, the better the overall grading, the better the pumping results will be.

If harsh, angular coarse aggregate must be used, it is especially important to make sure that both the fine and coarse are well graded, as previously described. A somewhat higher cement content and percentage of sand than normal will be helpful, and the maximum size of coarse aggregate should be about 3/4 inch. Entrainment of about 4 percent air will be beneficial. Some improvement in workability without excessive water may result from the use of a water-reducing admixture if this can be done under careful technical control.

A plastic, workable mix with a slump of about 3 to 6 inches is best. If the slump is too low, the friction of pumping is higher, resulting in less volume of concrete per unit of pump horsepower. However, segregation tendencies are lessened. Mixes that are too wet, on the other hand, are more apt to segregate, a condition that is liable to result in line blocks or plugs. Entrained air is sometimes desirable to enhance workability, especially with poorly graded or angular aggregates. Cement content is usually around 500 pounds per cubic yard, with a lower limit in the neighborhood of 420 pounds per cubic yard. Richer mixes can be pumped successfully. Pumps can handle 2 inch aggregate mixes, but 3/4 inch or 1 inch mixes are commonly used. In general, pumping difficulties that are caused by the concrete mix result from attempting to pump concrete with too much or too little slump; harsh, unworkable mixes caused by poorly graded or angular aggregates; concrete containing porous, highly absorptive aggregate, or aggregate too large for the machine or conduit.

A loss of slump during pumping is normal and should be taken into consideration when proportioning the concrete mixture. A loss of 1/2 inch per 100 feet of conduit is not unusual, the amount depending upon ambient temperature, length of line, pressure used to move the concrete, and moisture content of aggregate at time of mixing. The loss is greater for hose than for pipe, and might be as much as 3/4 inch per 100 feet.

Pumping Procedure

Before starting to pump concrete, the conduit should be primed by pumping a batch of mortar through the line to lubricate it. A rule of thumb is to pump 5 gallons of mortar for each 50 feet of 4 inch hose, using smaller amounts for smaller sizes of hose or pipe. Dump concrete into the pump hopper before the last of the mortar disappears into the pump loading chamber, pump at slow speed until concrete comes out the end of the delivery hose ,then speed up to normal pumping speed.

It is important to keep concrete in the pump hopper at all times, which makes necessary the careful dispatching and spacing of ready-mix trucks. From the standpoint of the pumper, it is better to have a ready-mix truck stand by for a few minutes rather than to shut down the pump to wait for concrete. However, having ready-mix trucks standing by waiting to discharge their concrete is neither efficient nor desirable. Nevertheless, once pumping has started it should not be interrupted as concrete standing idle in the line for any length of time might cause a line block.

Other causes of line blocks are slump too high; harsh, unworkable mix resulting from poor aggregate grading; mix too dry or under-sanded; bleeding of the concrete; a long line exposed to the hot sun; improper adjustment of the pump valves; dirty and dented pipe sections; or a kinked hose. When a block occurs in a hose, it can sometimes be located by walking back on the hose from the nozzle end and then dislodged by rapping the hose. It is more dangerous to attempt to dislodge a block by applying more pressure at the pump, as this will only worsen the condition or perhaps damage the equipment. Most pumps are designed so the direction of pumping can be reversed, thus drawing the concrete out of the line and sometimes relieving the block.

During an extended delay at the placing end, it is good practice to run the pump for a few strokes every few minutes, even though the concrete has to be wasted, in order to avoid a block in the line. This is especially necessary in hot weather.

Concrete can be pumped upward, but downhill pumping has a few special problems, because the concrete is apt to separate or segregate in the pipe unless there is resistance to pump against.

Resistance can be provided by a valve at the discharge end that can be adjusted to restrict the flow of concrete, or by inclining the final lengths of pipe or hose upward.

If it is necessary to run the line up and over an obstruction, then down a considerable distance, it may be advisable to install an air-release valve at the highest point of the line to prevent an accumulation of air that could result in a line block.

Upon completion of pumping, the pump and line are cleaned out by pumping clean water. To accomplish this, place a large sponge or rubber flush plug in the feed end of the conduit. (In the case of the vacuum-roller machine, the sponge is inserted in the pump suction line.) After being washed out, the hopper is filled with water and the pump started, forcing the remaining concrete out of the conduit, followed by the sponge or plug and water. One type of pump has a separate washout pump that supplies water to force the plug through the conduit. Hoppers, heads, cylinders and all parts must be cleaned to remove adhering concrete and mortar.

Pumping Lightweight Concrete

The main problem in pumping lightweight concrete is the loss of plasticity of the concrete resulting from absorption of water by the porous aggregate particles when the concrete undergoes pressure in the line. Some operators report a slump loss of about 3 inches between the time the concrete is dumped in the pump hopper and when it comes out of the hose. This had made necessary a slump of 7 inches or more at the pump. Such abnormally absorbed water subsequently escapes from the aggregate upon release of pressure after the concrete has been placed, resulting in undesirable excessive bleeding. Success in pumping can sometimes be at least partially assured if natural sand can be used for the fine aggregate, and if the coarse aggregate is prewetted before batching. In areas where they are available it has been reported that the use of coated coarse aggregate obviates the high-absorption problem.

If exposure or other considerations do not present restrictions, the use of coarse aggregate that has been treated by a vacuum absorption process has been found to give good results. This process fills the pores of the aggregate with water by treatment at the manufacturing plant, thus there is not absorption of water during pumping to cause a loss of plasticity of the concrete.

Placing Concrete

The correct term to describe the act of depositing and consolidating concrete in the forms is "placing". Concrete is not "poured". Although this expression is commonly accepted in our everyday conversation on the job. The use of this work owes its beginning to the days when sloppy, wet concrete really was poured and permitted to flow into place.

The first uses of concrete were in dams, heavy foundations and other relatively massive structures in which an earth-moist concrete was compacted in place with much hand labor. Later, when reinforced concrete was introduced, the narrow forms containing reinforcing steel required a wet, plastic consistency, and concrete passed into the era of very fluid mixes which were poured into place. However, research was pointing out the faults and shortcomings of high water contents. Then, about 1930, the introduction of high frequency vibration for consolidating concrete presented a practical way of handling relatively dry and unworkable mixes. Today, practically all concrete, regardless of its application, is consolidated by vibration and the need for wet mixes no longer exists.

It should be kept in mind that the slump of the concrete is prescribed by the specification, and is not to be determined by the condition or type of construction equipment. If the equipment will not handle concrete of the specified maximum slump, then the correction lies in the direction of proper equipment, not wetter mixers.

Depositing Concrete in the Forms

A basic rule is that concrete should be deposited as nearly as possible in its final location. It should be dropped as nearly as possible vertically. As long as the concrete is deposited near its final position without undue segregation, any method is acceptable. Drop chutes, or elephant trunks, are usually necessary to guide the concrete through congestions of reinforcing steel or other items. A crane bucket, moving along the top of a wall form, is satisfactory as long as the concrete is confined in a drop chute attached to the bucket. A hopper or series of hoppers, with drop chute attached, is commonly used when placing concrete in a wall form. Any reasonable height of unconfined fall is acceptable provided the form is clear and open so the fall is vertical and segregation does not occur. In practice, it is usually necessary to limit free fall to a few feet because of obstructions in the form. As a

practical safety measure, specifications usually limit the height of free fall.

Placing should be rapid enough to cover encrustation of mortar on steel or forms before the mortar dries. If the encrustation is on areas within the lift to be completed within a few hours it need not be removed. In using elephant trunks, the workmen should be cautioned to avoid pushing the bottom section at a considerable angle from the vertical. The bottom section should be vertical, although upper sections may be at an angle to facilitate placing of the concrete.

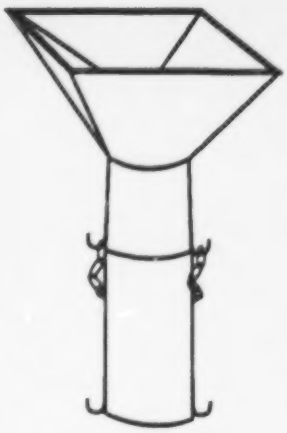

Figure 6-7
Hoppers with drop chutes are used to control free fall when placing concrete in high walls or columns.

Concrete in walls, footings, beams or any other structural components of appreciable height should be placed in horizontal layers not exceeding about 18 inches in depth, unless another thickness is specified, starting at the ends or corners of the forms and working toward the center. The first layer on a rock foundation or construction joint should be preceded by a layer of mortar, not over 1/2 inch thick, well broomed into the surface, or by a layer of concrete containing one-half the amount of coarse aggregate in the regular mix, spread to a thickness of at least 2 inches. A satisfactory mortar is made by omitting the coarse aggregate from a batch of concrete, using just enough water to provide a soft, mushy consistency. Any admixture used in the concrete should be included in the mortar batch also. Subsequent layers, continuing to the full height of the structure, should be placed and consolidated before the underlying layer has hardened. As the top of the placement is approached a drier concrete consistency should be used.

In some work, such as beneath openings in walls, it may be necessary to move concrete over a short distance horizontally. Such horizontal movement should be kept to a minimum.

In placing concrete in high, thin walls or similar structural units, it is common practice to provide ports or windows in the forms. If possible, these windows should be made on a surface that will not be exposed to view in the finished structure, such as the back side of a wingwall on a highway structure. When the level of the fresh concrete within the structure approaches the window, the hole should be closed as tightly and neatly as possible. Because of the danger of segregation resulting from a high velocity stream of concrete entering the form at an angle, and because of the surface blemishes usually resulting in the area where the hole was closed, it is best to avoid use of these ports, if at all possible, or provide a collecting hopper outside the opening.

Concrete in cast-in-place piles and deep caisson footings must, of necessity, be dropped a considerable distance. Placement should be as nearly continuous as possible, as consolidation in the lower portion of the footing depends upon the impact of succeeding increments of concrete. A plastic consistency of about 4 inch slump should be adequate, although a particularly deep or narrow form may necessitate a slump as high as 6 inches.

In placing a slab, batches of concrete should be placed against or towards the preceding ones, not away from them. Batches should not be dumped in separate, individual piles. If the slab is on a slope, placing should start at the lower end of the slope.

In a structure consisting of monolithic columns, beams and slabs, concrete should be placed to the top of the columns or beams, then allowed to set for two or three hours, depending on the weather, for settlement to take place, then the slab may be placed. If this procedure is not followed, cracks are liable to form where the slab joins the beam, or the beam joins the column.

Waste molds, or other molds for intricate architectural details, should be protected from accumulations of mortar or other damage while the underlying concrete is being placed. One method of accomplishing this is to cover the inside of the mold with canvas, polyethylene or similar material which is removed when the level of the concrete in the form reaches the mold.

Mass concrete in dams and similar massive structures is usually placed in lifts of 5 or 7 1/2 foot depth, each lift consisting of several layers. In order to avoid cold joints, these layers are carried across the form in a series of steps, the first step being the mortar, then Step No. 2 and so on until the final step

at the top. Concrete contains cobbles as large as 6 inches in diameter, has a low cement content, and is placed at a slump of 1 or 2 inches, or even less. Segregation is an ever-present problem. Buckets, which may have a capacity of as much as 12 cubic yards, should have full-opening bottoms that discharge the concrete vertically and quickly.

Placing Concrete During Rain

Under rain conditions, usually a quick decision is necessary so trouble should be forestalled by proper preparation and planning. A supply of protective coverings should be available nearby. Placing of concrete should not be commenced during a rainstorm, but should be delayed until there is reasonable assurance that the placement can be completed before rain starts. If rain starts while concrete placing is in progress and the work must be continued and no construction joint can be made, no damage will be done during a light drizzle provided the following precautions are taken:

1. Place the concrete at a slightly lower slump.
2. Dry up puddles of water collected on the foundation or old concrete in the joint before new concrete is placed.
3. Cover the working area with tarps or tents, and keep them in place until the concrete has set.
4. Keep the surface of the new concrete on a slight slope so water will run off.
5. Avoid working the surface of a new concrete. After the concrete reaches a grade, a slight slope should be provided, if feasible, for drainage.
6. If the rain is so heavy that it is not possible to dry up the puddles or keep the rain from washing the surface, work should be discontinued. The foreman or inspector should consult his supervisor regarding the placing of bulkheads and dowels and making a joint.

During thunder showers of short duration, it is frequently possible to cover the forms with a temporary cover and suspend work until the storm passes.

Special Placing Methods

There are a number of occasions that present unique problems in handling, placing and consolidating concrete. Among these are slip forms, underwater placing, preplaced aggregate concrete and several others.

In some cases it becomes necessary to modify good concreting practices. When this is done, it is done knowingly and carefully, with safeguards and controls to compensate for the modifications. Modification of good practices should not be construed as license to eliminate all controls.

Consolidation

Once the concrete has been deposited in the forms, it has to be compacted or consolidated, to make it into a solid, uniform mass, without voids, rock pockets or sand streaks. Many years ago, consolidation was accomplished by laborers wielding a variety of spades, tampers and similar tools. Now nearly all concrete is consolidated with high-frequency vibrators. Vibrators come in many sizes and kinds, but all can be grouped as either internal immersion vibrators or external vibrators, depending on whether they operate immersed in the concrete, or apply their vibration externally.

Equipment

Internal spud vibrators to be immersed in the concrete, operating at speeds of 5500 to 15,000 vpm (vibrations per minute), range in size from 3/4 inch diameter to 6 1/2 inch diameter with head lengths from 10 to 28 inches. The larger ones for mass concrete operate in the lower range of frequency; many require two men to handle them. Most vibrators are either electric or air-powered, and some are driven by small gasoline engines. The

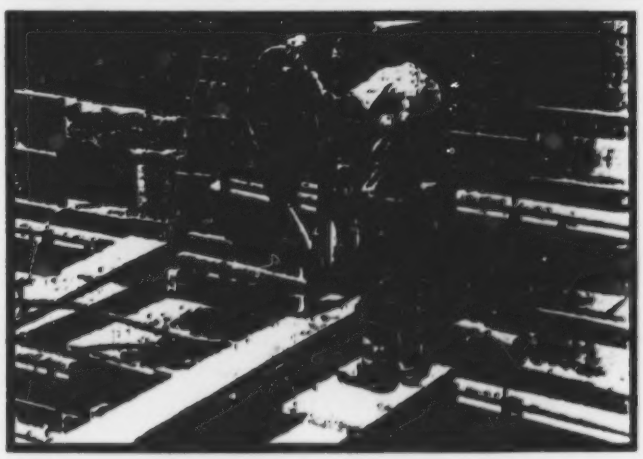

Figure 6-8
Immersion vibrator being used to consolidate concrete in wall form.

motor may be in the head of the vibrating unit, or the vibrating unit may be connected to the motor by means of a flexible shaft. This classification includes the gang-mounted and tube vibrators used on paving machines, as well as vibrators for structural concrete. Vibrators used in building construction include those from 3/4 inches to 3 1/2 inch diameter with speeds from 8000 to 15,000 vpm. Vibration is accomplished by the rotation of an eccentrically loaded shaft. Some manufacturers furnish a frequency converter to change normal 60-cycle electric current into a high-frequency current, the better to operate the vibrator at these high speeds.

External vibrators include form vibrators that are attached to the forms and vibrate the concrete by vibrating the forms, surface vibrators that apply vibration to the surface of a slab, and vibrating tables used in precasting plants.

Form vibrators operating at a minimum speed as low as 1000 vpm are attached to the exterior of the mold or form. They are used in locations where it is not possible to use internal vibrators, such as in tunnel linings or heavily congested forms; they are also used for making pipe, masonry units and many other types of precast concrete. Pneumatically driven units develop vibration by the rotation of an eccentric weight. The speed can be carried by changing the volume of air supplied. One type; consisting of a loose weight inside a circular housing, is known as the "police whistle" because of its construction. Electric vibrators are either the rotary type or electromagnetic type, the latter consisting of a heavy armature that vibrates at synchronous speed (3600 vpm on 60-cycle current).

Figure 6-9
Screed vibrator being used to consolidate concrete in floor slab.

The second group of external vibrators includes surface, pan or screed vibrators that operate on the surface of a floor, slab or pavement. Minimum frequency should be 3000 vpm. Consolidation of the concrete in thin slabs is accomplished by drawing a vibrating screed or strike-off unit slowly over the surface. Slabs up to 8 inches thick can be consolidated adequately. Thicker slabs require additional internal vibration. Screed lengths as long as 40 feet have been used. In addition to consolidating the concrete in the slab, the unit strikes off the surface and prepares it for final finishing. Pans, grids and rollers equipped with vibrators of some kind fit into this category.

A third group covers the table vibrators that are used in precasting plants. These are not normally encountered on construction sites. They accomplish their compaction either by means of external vibrators attached to the table, or by means of a very slow, high amplitude vibration induced by raising and dropping the table on which the form for the concrete unit is attached.

The frequency of vibration can be determined by the use of a vibrating reed tachometer. The instrument can be held against the vibrator, while the latter is immersed in the concrete, or even on the formwork nearby.

Operation

Concrete should be consolidated to the maximum practicable density, so it is free of pockets of coarse aggregate and entrapped air, and closes snugly against all surfaces of forms and embedded materials. Vibrators should be applied to the concrete immediately after it is deposited. In consolidating each layer of concrete, the vibrator should be operated in a nearly vertical position and the vibrating head should penetrate slightly into and revibrate the concrete in the upper portion of the underlying layers.

Application of vibrators should be at points uniformly spaced, close enough together to insure complete consolidation (usually not more than twice the radius of which the vibration is visibly effective), and of sufficient duration to thoroughly consolidate the concrete, ordinarily 5 to 15 seconds per insertion. Vibrators should be used sparingly or not at all in wet, high-slump concrete. Harsh, low-slump concrete requires more vibration than concrete of moderate slump. Vibrators should not be dragged through the concrete nor should they be used for the

purpose of moving the concrete about in the forms.

The vibrating head should not be held against the reinforcement. The head should be withdrawn from the concrete slowly and immediately re-inserted. Allowing the vibrator to run for a long period of time with the head out of the concrete can damage it. The running vibrator should not come in contact with the form as a rough spot may be caused on the surface of the concrete.

Vibrators cannot recombine concrete that has already segregated. If segregation has occurred because of improper handling techniques, concentrations of rock should be broken up by shoveling the rocks onto areas of concrete containing a sufficiency of sand.

Completion of vibration is indicated when the surface of the concrete takes on a flattened glistening appearance, the rise of entrapped air bubbles ceases, the coarse aggregate blends into the surface but does not disappear, and the vibrator, after an initial slowdown when first inserted into the concrete, resumes its normal speed.

Over vibration can and does occur, especially when overly wet mixes are being placed. The correction is to reduce the slump first, then adjust the amount of vibration. If concrete has been over vibrated, the coarse aggregate will have sunk below the surface, and the surface may have a frothy appearance.

Revibration occurs when the vibrator, in consolidating a layer of concrete, penetrates into the layer below to weld or unite the two layers. The intentional revibration of previously placed concrete occurs when a running vibrator will sink of its own weight into the concrete. The general effect of revibration is improved strength, durability and appearance. It tends to reduce water pockets under horizontal reinforcing steel, and reduce the appearance of settlement cracks. In moderation, the net effect of revibration is beneficial. It must, however, be done by experienced operators under adequate supervision.

When consolidating concrete against intricate form faces for architectural work where the surface must be as flawless as possible, vibration should be supplemented by spading or rodding along the forms, especially in corner and angles. Placing the concrete in thin layers is also beneficial.

Form vibrators are occasionally used in structural applications but should not be depended on to consolidate concrete if internal spud vibrators can penetrate to the area in question. This may take a little ingenuity in forming and placing but is well worth the extra effort. The configuration of some structures requires that some of the concrete be flowed in place, in which case form vibrators can be of considerable value.

Article #18: Concrete Vibration

The why and how of consolidating concrete
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What factor has a greater effect on concrete compressive strength than any other? Most engineers would say water-cement ratio ... as water-cement ratio increases strength decreases. Duff Abrams showed this in 1919, and Abrams' law is the principle behind most concreting proportioning methods used today. But Abrams ran his tests on fully consolidated concrete. Unless concrete is properly consolidated, voids reduce strength regardless of the water-cement ratio and the effect is significant.

Right after it's placed, concrete contains as much as 20% entrapped air. The amount varies with mix type and slump, form size and shape, the amount of reinforcing steel, and the concrete placement method. At a constant water-cement ratio, each percent of air decreases concrete strength by driving out entrapped air. It also improves bond strength and decreases concrete permeability.

Vibration is a two-part process

How does vibration consolidate concrete? A vibrator creates pressure waves that separate aggregate particles, reducing friction between them. Piles of concrete flatten as the concrete flows around reinforcing steel and up to the form face. Large voids (honeycomb) disappear.

But making the concrete flowable doesn't finish the compaction process. Almost simultaneously, a second stage starts to occur as entrapped air bubbles rise to the surface. This deaeration process continues after the concrete has flattened out.

Until both vibration stages are complete, the concrete isn't fully consolidated. If the vibrator is removed too soon, some of the smaller bubbles won't have time to rise to the surface. Vibration must continue until most of the air entrapped during placement is removed. It's usually not practical, though, to remove all the entrapped air with standard vibrating equipment.

Different vibrators for different jobs

The earliest form of equipment used as a vibrator was a rod stuck into the concrete, pushed down and pulled up. Rodding works for concretes with slumps greater than 3 inches, but it's rarely used because of the costly labor required. Because rodding doesn't put extra pressure on forms, however, it has helped more than one contractor complete a concrete pour when forms were bulging.

The most common vibrator used is the electric, flexible shaft type. Other types include electric motor-in-head, pneumatic, and hydraulic. Vibrator output, usually expressed as a frequency, is controlled in a different way for each type of vibrator:

- An electric vibrator uses voltage
- A pneumatic vibrator uses air pressure
- A hydraulic vibrator uses pressure and flow rate of hydraulic fluid.

On the jobsite the contractor can check the operating performance of his equipment by measuring frequency. If it's low he should check for voltage fluctuations, air pressure losses, or hydraulic pressure drops. The type of vibrator must match the requirements of the concrete and the jobsite. Frequency rates determine the amount of vibration time required to complete the two-stage consolidation process.

In the 1960s, vibration frequencies were much lower. To compact a 1/2 inch slump concrete took 90 seconds at 4,000 vibrations per minute (vpm), 45 seconds at 5,000 vpm, and 25 seconds at 6,000 vpm. Today's typical frequency of 15,000 vpm requires only 5 to 15 seconds of vibration time. Internal vibrators chosen for most jobs have a frequency of 12,000 to 17,000 vpm in air. The common flexible shaft-type vibrator reduces its frequency by about 20% when immersed in concrete. Motor-in-head types provide a constant frequency when in air or concrete.

How to use an internal vibrator

Producing a dense concrete without segregation requires an experienced vibrator operator. Inexperienced operators tend to merely flatten the concrete because they don't vibrate long enough to deaerate the concrete. Undervibration is more common than overvibration because of a worker's effort to keep up with the concrete or to increase productivity.

The operator can judge whether or not vibration is complete by watching the concrete surface. When no more large bubbles escape, consolidation is adequate. Skilled operators also listen to the pitch or tone of the vibrator motor. When an immersion vibrator is inserted in concrete, the frequency usually drops off, then increases, becoming constant when the concrete is free of entrapped air.

Never use a vibrator to move concrete laterally
Concrete should be carefully deposited in layers as close to its final position in the form. As each layer is placed, insert the vibrator vertically. The distance between insertions should be about 1 1/2 times the radius of action (usually 12 to 24 inches). Radius of action is a distance from the vibrator head within which consolidation occurs. It varies with equipment and concrete mix.

Walls and columns
Special techniques are necessary to blend layers of concrete in walls and columns. Let the vibrator penetrate quickly to the bottom of the layer and at least 6 inches into the preceding layer. Then move the vibrator up and down, generally for 5 to 15 seconds, to blend the layers. Withdraw the vibrator gradually with a series of rapid up and down motions.

Elevated beams and slabs
Beams and joists placed monolithically with slabs should be vibrated separately before slab placement. Place the slab concrete after vibrating the beam, but before the beam concrete is set. Allow the vibrator to penetrate through the slab into the previously placed beam to blend the two structural elements.

Undervibration vs. overvibration
Undervibration is far more common than overvibration. Good quality normal-weight concrete is not readily susceptible to the problems caused by overvibration , so when in doubt, vibrate more.

The problems associated with undervibration include:

- ⊘ Honeycombing
- ⊘ Excessive entrapped air
- ⊘ Sand streaks
- ⊘ Cold joints
- ⊘ Subsidence cracking

The problems associated with overvibration include:

- ⊘ Segregation
- ⊘ Sand streaks
- ⊘ Loss of entrained air
- ⊘ Form deflection
- ⊘ Form damage or failure

Overvibrating, because it causes entrained air loss, might be expected to decrease freeze-thaw resistance. Research results don't bear this out, however. In one study, overvibration of low-slump, air-entrained concrete had no effect on freeze-thaw resistance. Overvibration should not be a concern unless high-slump, improperly proportioned concrete is being placed.

Vibrating around congested reinforcement
To provide good concrete-to-steel bond, vibration is especially important in areas congested with rebar. Vibration alone doesn't solve the problem. Other actions must be taken to help complete concrete consolidation, such as:

- Using admixtures to increase flowability but limit segregation
- Changing mix proportions or ingredients to increase flowability
- Designing the reinforcing for ease of concrete placing

To achieve proper consolidation by internal vibration in congested areas, the designer should provide obstruction-free vertical access of 4x6 inch minimum openings to insert the vibrator. Horizontal spacing of these openings should not exceed 24 inches or 1 1/2 times the vibrator's radius of action. Engineers designing congested reinforcement should also design for proper consolidation, otherwise contractors can't always guarantee adequate concrete-to-steel bond.

Tests Prove Consolidation Affects Compressive Strength
A study by Construction Technologies Laboratories, Inc., Skokie, Illinois (Ref. 2), used six different concrete mixes to establish the effect of consolidation on the compressive strength, bond stress, and chloride permeability of concrete. The six mixes included limestone and gravel aggregates, a cement content of either 520 or 600 pounds per cubic yard, an air content from 5% to 10%, and had a slump of 1 to 2 inches. The results dramatically underscore the need for consolidation. Compressive

strength was reduced by about 30% for each 5% decrease in degree of consolidation. Bond stress suffered a loss of about 50% for a 5% decrease in degree of consolidation. Poorly consolidated concretes also were more permeable to chloride ions. Before vibration, percent consolidation for field concrete is typically at 80% to 95%. After vibration it's usually between 95% and 100%.

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2. Whiting, D., G.W. Seegebrecht, and S. Tayabji, "Effect of Degree of Consolidation on Some important Properties of Concrete", SP-96, Consolidation of Concrete, American Concrete Institute.
3. Olsen, Mikael, "Energy Requirements for Consolidation of Concrete During Internal Vibration", SP-96, Consolidation of Concrete, American Concrete Institute.
4. Troxell, Davis, & Kelly, Composition and Properties of Concrete, McGraw-hill, New York, New York, 1968.

SECTION VII: FINISHING AND CURING

Pages 104 - 107 Questions on film *Finishing and Curing Quality Concrete*

Pages 108 - 111 Article 19: *Finishing Concrete*

Pages 112 - 113 Article 20: *Curing Concrete*

Trainee Section Objectives

1. To become aware of proper finishing tools and procedures.
2. To become aware of proper curing and/or protection methods for newly placed concrete.
3. To demonstrate competency in selecting and implementing a curing procedure for current or expected environmental conditions.

"Finishing and Curing Quality Concrete"

Questions on information in the Portland Cement Association film

1. What 2 variables must be controlled to get optimum hydration?

2. What does the film recommend about form removal?

3. What is done after the forms are removed?

4. What are the timing and/or strength factors for abrasive finishing?....bush hammering finishing?

5. What 4 methods are used in the exposed aggregate finishing process?

6. Are strike off and bullfloating part of the finishing process?

7. What 2 criteria are used to determine when to start the finishing process?

8. What is the recommended technique for using the edging tool? What does edging accomplish?

9. What is good procedure in keeping a control joint to line and grade?

10. What does a control joint actually do?

11. What is the finishing process called that follows edging and control jointing?...Can this process be done by machine?

12. What 3 things does floating do?

13. What immediately follows floating in the finishing process? When does this take place?

14. Can troweling take place before the floating is done?...What does troweling do?

15. What is the recommendation on tool size and techniques with first troweling?

16. What happens when sufficient troweling takes place?

17. When is a concrete surface broomed?...Should the broom be wet or dry?

18. What does the film recommend about sawing joints in concrete?

19. What does the curing process do to concrete?

20. What is the best method for curing concrete?...Can this process be intermittent?

21. What are 3 different methods used to water cure?

22. Can other natural materials be used for curing?...What should be determined before using these materials?

23. What does a sealant do to the concrete?...What are 3 kinds of sealants?

24. What are the 2 types of curing compounds?

25. What are 2 requirements when using a curing compound?

26. How long should forms remain on the concrete?...When forms are on walls, what additional curing process does the film recommend?

27. What temperature does the film recommend keeping concrete at in cold weather?

28. What 5 methods does the film discuss to control temperature during cold weather concreting?

Article 19: FINISHING CONCRETE

The finishing operations of edging, jointing, floating, troweling, and brooming must wait until all bleed water has left the surface and the concrete stiffens slightly. This waiting period, which is absolutely essential to obtain durable surfaces, varies with the wind, temperature, and relative humidity of the atmosphere and with the type and temperature of the concrete. On hot, dry, windy days, the waiting period is very short; on cool, humid days, it can be several hours. With air-entrained concrete, there may be little or no waiting. Begin finishing when the water sheen is gone and the concrete can sustain foot pressure with only about 1/4-in. indentation. A water sheen may not be visible on air-entrained concrete.

Edging

Edging is the first operation. It produces a neat, rounded edge that prevents chipping or damage, especially when forms are removed. Edging also compacts and hardens the concrete surface next to the form where floats and trowels are less effective.

Edging tools are made of steel and bronze. Stainless steel edgers with 1/2-in. radius are recommended for walks, drives, and patios. Preliminary edging should be done with an edging tool that is longer and wider, approximately 10x6 in.

Immediately after using the bull float or darby, cut the concrete away from the forms to a depth of 1 in., using a pointed mason trowel or a margin trowel.

Figure 7-1
Edging produces a neat rounded surface that prevents chipping.

Delay preliminary edging until the concrete has set sufficiently to hold the shape of the edger tool. The edger should be held flat on the concrete surface. The front of the edger should be tilted up slightly when moving the tool in the forward direction. When moving the tool backward over the edge, the rear of the tool should be tilted slightly. Caution is necessary to prevent the edger from leaving too deep an impression, as these indentations may be difficult to remove in subsequent finishing operations. In some cases, edging is required after each finishing operation, with final edging done before or after brooming.

Jointing

While edging is being done, or immediately after, the slab is jointed or grooved. Jointing is a most important finishing operation. Proper jointing practices can eliminate unsightly random cracks. Like other materials used in construction, concrete contracts and expands slightly under varying conditions of moisture and temperature. When newly placed, concrete attains its largest volume. When dry and cold, it contracts to its smallest volume. These changes in volume are normal in all concrete, but unless provisions are made to control them, cracks may result. Effective control is obtained with control joints and isolation joints.

Figure 7-2
Jointing provides control joints that eliminate unsightly cracking.

Control joints, sometimes called contraction joints, are made with a hand tool, sawed, or formed by using wood divider strips. The tooled or sawed joint should extend into the slab one-fourth to one-fifth of slab thickness. A cut of this depth provides a weakened section that induces cracking to occur beneath the joint where it is not visible.

In driveways and sidewalks, control joints should be spaced at intervals about equal to the slab width. Drives and walks wider than about 10 to 12 ft. should have a longitudinal control joint down the center.

Spacing of control joints in patios should not exceed 10 ft. in either direction. If possible, the panels formed by control joints in walks, drives, and patios should be approximately square. Panels with excessive length-to-width ratio (more than 1 1/2 to 1) are likely to crack. As a general rule, the smaller the panel, the less likelihood of random cracking. All control joints should be continuous, not staggered or offset.

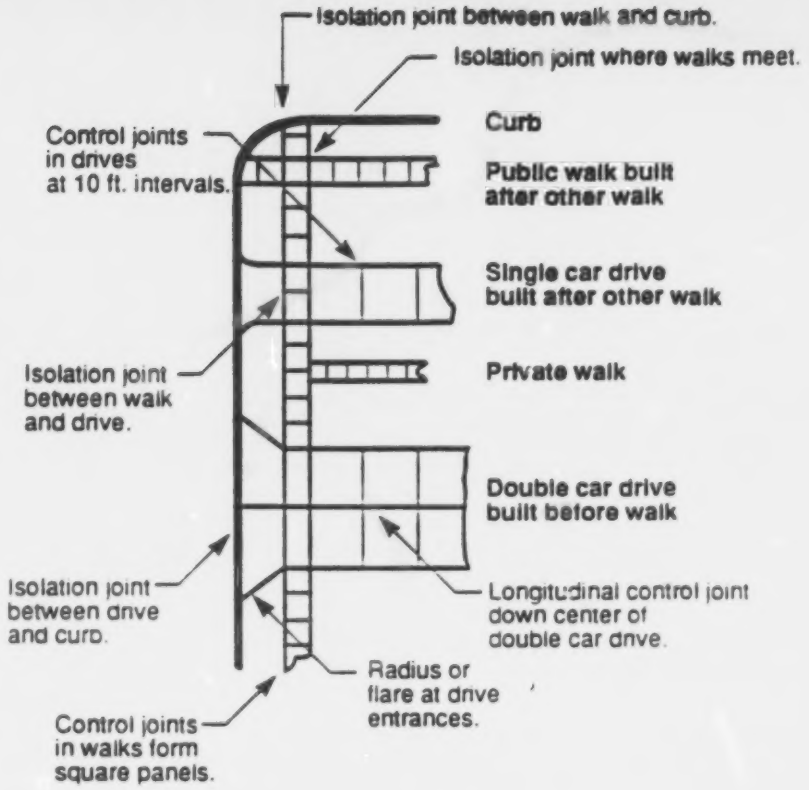
Isolation joint between walk and curb.
Isolation joint where walks meet.
Curb
Control joints in drives at 10 ft. intervals.
Public walk built after other walk
Single car drive built after other walk
Isolation joint between walk and drive.
Private walk
Double car drive built before walk
Isolation joint between drive and curb.
Longitudinal control joint down center of double car drive.
Radius or flare at drive entrances.
Control joints in walks form square panels.

Figure 7-3
Recommended locations of control and isolation joints in walks and drives.

Hand tools for jointing are called groovers or jointers. Like edgers, they are made of stainless steel and other metals and are available in various sizes and styles. The radius of a groover should be 1/4 to 1/2 in. The bit (cutting edge) should be deep enough to cut the slab a minimum of one-fifth, and preferably one-fourth, of the depth. Groovers with worn-out or shallow bits should not be used for making control joints, but may be used for decorative scoring of the surface.

It is good practice to mark the location of each joint with a string or chalk line on both side forms and on the concrete surface. A straight 1 by board at least 6 in. wide should be used to guide the groover. The board should rest on the side forms and be perpendicular to the edges of the slab. The groover should be held against the side of the board as it is moved across the slab.

To start the joint, the groover should be pushed into the concrete and moved forward while applying pressure to the back of the tool. After the joint is cut, the tool should be turned around and pulled back over the groove; this gives it a smooth finish. If the concrete has stiffened to the point where the groover will not penetrate easily to the proper depth, a hand axe can be used to push through the concrete. The groover should then be used to finish the joint.

Instead of being hand-tooled, control joints can be cut with a concrete saw. For small jobs, an electric handsaw equipped with a masonry cutting blade can be used. To function properly, a sawed joint must be cut as deep as a hand-tooled joint, namely one-fourth to one-fifth of the slab thickness. Sawing should be done as soon as the surface is firm enough not to be torn or damaged by the blade. This is normally 4 to 12 hours after the concrete hardens. A slight raveling of the sawed edges is permissible and indicates proper timing of the sawing operation. If sawing is delayed too long the concrete may crack before it is sawed, or cracks may develop ahead of the saw.

The other type of joint required to control random cracks is the isolation joint, sometimes referred to as an expansion joint. It consists of a premolded strip

of fiber material that extends the full depth of the slab or slightly below it. It need not exceed 1/2 in. in thickness, and in most instances 1/4 in. is sufficient. Isolation joints are required at points of potential stress—for example, around rigid objects such as manholes, fireplugs, and utility poles. They are also required at intersections of walks and drives and at points where slabs abut existing buildings or curbs.

Isolation joints should be flush with the finished surface or, better still, about 1/4 in. below. Joints that protrude above the surface are a safety hazard. For this reason, joint materials that extrude when compressed should not be used.

A construction joint is required where concreting operations are temporarily suspended, as at the end of a day's work. Construction joints should be avoided when possible; but if necessary, they should be planned and located so as to act as control joints. A keyway is required to provide load transfer across a construction joint. This ensures that future slabs will remain level with previously cast concrete. The keyway may be formed by fastening metal, wood, or premolded key material to a wood bulkhead. Concrete above the joint should be hand tooled or sawed to match the control joints in appearance.

Edging and jointing must be done with care since these operations affect the appearance of the finished slab. Deep impressions left in the surface by hand edgers and groovers may be difficult to remove during subsequent finishing operations. On the other hand, such impressions purposely made can be decorative.

Floating

Following edging and jointing, the surface is floated. Floating has three purposes: (1) to embed large aggregate just below the surface; (2) to remove any imperfections left in the surface by previous operations; and (3) to compact the concrete and consolidate mortar at the surface in preparation for any further finishing operations that may be desired.

Hand floats are made of metal, wood, plastic, and composition materials. Magnesium floats are light, strong, and slide easily over a concrete surface. They are recommended for most work, especially for air entrained concrete. Wood floats drag more, hence require greater effort to use; but the wood produces a rougher texture, which may be preferred when good skid-resistance is required and floating is used as the final finish.

Figure 7-4
Floating using a magnesium float removes imperfections left by edging and consolidates mortar at the surface.

The hand float should be held flat on the concrete surface and moved with a slight sawing motion in a sweeping arc to fill in holes, cut off lumps, and smooth ridges. On large slabs or for volume work, power floats can be used to advantage to reduce finishing time.

Floating produces a relatively even (but not smooth) texture. Since this texture has good skid-resistance, floating is often used as a final finish. In such cases, it may be necessary to float the surface a second time after some hardening has taken place, to impart the desired final texture to the concrete.

Marks left by edgers and groovers are removed during floating. Therefore, if they are desired for decorative purposes, the edger or groover can be rerun after final floating.

Troweling

Immediately after floating, the surface can be troweled. Troweling produces a smooth, hard, dense surface. Troweling should never be done on a surface that has not been floated either by hand or power. Troweling after bull-floating or darbying is not sufficient.

On large slabs where the finisher cannot reach the entire surface, he must work on kneeboards. This operation should be delayed until the concrete has hardened enough that water and fine material are not brought to the surface. Too long a delay, of course, will result in a surface that is too hard to finish. The tendency in many cases, however, is to start when the concrete is too soft. Such premature

Figure 7-5
Troweling with a steel hand trowel

finishing may cause scaling or dusting, as noted previously.

Hand trowels are made of high-quality steel in various sizes. Normally at least two sizes are used. For the first troweling, one of the larger tools—18x4 3/4 in., for example – is recommended. Shorter and narrower trowels are used for additional trowelings as the concrete sets and becomes harder. For the final troweling, a 12x3-in. trowel, known as a fanning trowel, is recommended. When one trowel is used for the entire operation, it should measure about 14x4 in. Power trowels can be used to advantage to reduce finishing time on large slabs or for volume work.

For the first troweling, whether by hand or power, the trowel blade should be held flat on the surface. If it is tilted, ripples are made that are difficult to remove later without tearing the surface and causing popouts. The hand trowel is used in a sweeping arc motion, each pass overlapping one-half of the previous pass. In this manner, each troweling covers the surface twice. The first troweling may be sufficient to produce a surface free of defects, but additional trowelings may be used to increase smoothness and hardness.

There should be a lapse of time after the first troweling to permit the concrete to become harder. When only a slight indentation is made by pressing a hand against the surface, the second troweling should begin, using a smaller trowel with the blade tilted slightly.

If the desired finish is not obtained with the second troweling, there should be a third troweling after another lapse of time. The final pass should make a ringing sound and the tilted blade moves over the hardening surface.

When the first troweling is done by machine, at least one additional troweling by hand is required to remove small irregularities. If necessary, tooled edges and joints should be rerun after troweling to maintain uniformity and true lines.

Brooming

A smooth-troweled slab is easy to clean but can be slippery when wet. For better footing, it can be roughened slightly by brooming to produce a nonslip surface.

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Article 20: Curing Concrete

Curing is one of the most important steps in concrete construction and, regrettably, one of the most neglected. Proper curing greatly increases the strength and durability of concrete.

Purpose of Curing

The hardening of concrete is brought about by chemical reactions between cement and water. This process, called hydration, continues only if water and a suitable temperature are available. When too much water is lost by evaporation from newly placed concrete, hydration stops. At near freezing temperatures (32° F), hydration slows almost to a standstill. Under these conditions, concrete ceases to gain strength and other desirable properties. The purpose of curing is to maintain conditions under which concrete hardens by keeping it moist and warm.

Methods of Curing

Moist-curing is done in a number of ways: for example, by supplying water with wet coverings, sprinkling, or ponding to offset loss of moisture; or by sealing the concrete surface with plastic sheeting, waterproof paper, or curing compounds to prevent loss of moisture.

Supplying additional water is the more effective method. Burlap, the most commonly used wet covering, should be free of any substance that may be harmful to concrete or cause discoloration. New burlap should be washed before use. The burlap should be placed as soon as the concrete is hard enough to withstand surface damage and sprinkled periodically to keep the concrete surface continuously moist. Water curing with lawn sprinklers, nozzles, or soaking hoses must be continuous so that there is no chance of partial drying during the curing period. Ponding is very effective for small jobs that are reasonably level. Sand or earth dikes are used to confine water on the slab. A sufficient depth of water must be maintained to prevent dry spots.

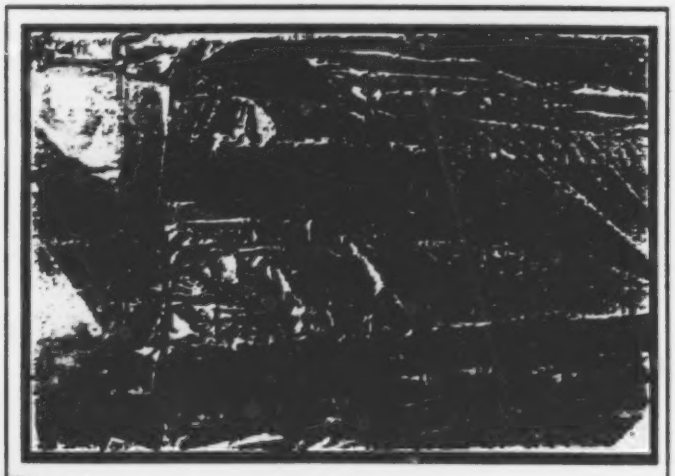

Figure 7-6 and 7-7
Curing with plastic sheeting used as a moisture barrier.

Curing methods intended to seal the surface are not quite as effective as methods that supply water, but they are widely used for their convenience. Moisture barriers such as plastic sheeting and waterproof paper are popular. They do not require periodic additions of water, but they must be laid flat, thoroughly sealed at joints, and anchored carefully along edges. Curing with these materials may cause patchy discoloration, especially if the concrete contains calcium chloride and has been finished by hard steel troweling. This discoloration is experienced when the plastic or paper becomes wrinkled. It is difficult and time consuming on a project of significant size to smooth out the wrinkles that are apt to form. Accordingly, other means of curing should be used when uniform color is important.

Pigmented curing compounds provide the easiest and most convenient method of curing. These compounds are applied by spraying soon after the final finishing operation. The surface should be damp, but not wet with free water. Complete coverage is essential. A second coat, applied at right angles to the first, is recommended if there is any doubt about the thoroughness of the coverage.

Curing compounds are not recommended during late fall in northern states and Canada where de-icers are used to melt ice and snow. Use of curing compounds under these conditions may prevent proper air-drying of the concrete, which is necessary to enhance resistance to scaling caused by use of de-icers.

Curing Period

Curing should be started as soon as it is possible to do so without damaging the surface. It should continue for a period of 5 days in warm weather (70°F or higher) or 7 days in cooler weather (50-70° F). The temperature of the concrete must not be allowed to fall below 50° F during the curing period.

Cold Weather

Ideally, walks, drives, patios, and steps should be built well in advance of cold weather. When placed during warm weather, there is plenty of time for concrete to develop strength to resist freezing, thawing, and chemical de-icers.

However, a good job can also be done during cold weather if proper methods are followed. Heated concrete should be ordered so that the temperature of the mix does not fall below 50° F during placing, finishing, and curing. When there is danger of freezing, particularly when average daily temperatures are below 40° F, concrete should be kept warm during curing. Insulating blankets or 12 to 24 in. of dry straw can be used. Straw should be covered with canvas, waterproof paper, or plastic sheeting to keep it dry and in place. The effectiveness of the protection can be checked by placing a thermometer under the covering. Slab edges and corners are most vulnerable to freezing and should be carefully protected.

During cold weather, high-early-strength concrete may be used to speed up setting time and strength development. This can reduce the curing period from 7 to 3 days, but a minimum temperature of 50° F must be maintained in the concrete for 3 days. High-early-strength concrete is made by using (1) Type III(High-Early-Strength) cement, (2) an extra 100 lb. of cement in each cubic yard of concrete, or (3) up to 2 percent calcium chloride by weight of cement. Due to problems that may occur with use of chlorides, method 1 or 2 is recommended.

Hot Weather

In hot weather, precautions may be required to prevent rapid loss of surface moisture from the concrete. This can cause finishing difficulties and cracks (known as plastic shrinkage cracks) in the fresh concrete soon after placing.

Some helpful measures to prevent these problems are: (1) dampening the subgrade and forms; (2) minimizing finishing time by having sufficient manpower on hand; (3) erecting sunshades and windbreaks; (4) using temporary coverings such as wet burlap or plastic sheeting during finishing and uncovering only a small area at a time just ahead of the finishers; (5) using light fog sprays to prevent evaporation from concrete; and (6) starting curing as soon as possible, using continuous wet methods or white pigmented curing compounds. During very hot, dry weather, consideration should be given to placing and finishing during the cooler early morning or late evening hours.

Use of De-icers

De-icing chemicals* used to melt ice and snow can cause surface scaling. The extent of scaling depends upon the amount of salt used and the frequency of use. Unfortunately, de-icers can be applied accidentally in various ways, such as by drippings from the underside of vehicles. Scaling is much more severe in poorly drained areas because the de-icer solution is retained on the concrete surface during freezing and thawing.

Air entrainment has proved effective in preventing surface scaling and is recommended for all concretes that may come in contact with de-icing chemicals. In addition, about 2 to 4 weeks of air-drying after the curing period will greatly increase air-entrained concrete's resistance to de-icers.

*Ammonium nitrate and ammonium sulfate have been sold as de-icers. These materials react chemically with concrete and cause disintegration. Their use should be strictly prohibited.

SECTION VIII: STRIPPING AND CLEAN UP

Pages 115 - 116 Article 21: Stripping and Clean Up

Trainee Section Objectives

1. To become aware of proper form removal (stripping) procedures.
2. To demonstrate competency at form removal without damage to newly placed concrete.
3. To demonstrate competency in form cleaning, stacking, and storage procedures.

Article 21: Stripping and Cleanup

Careless workmen can cancel out the value of good detailing and planning by indiscriminate use of the wrecking bar. A pinch bar or other metal tool should never be placed against architectural concrete to wedge forms loose. If it is necessary to wedge between the concrete and the forms, only wooden wedges should be used. Once formwork is removed, architectural surfaces must be protected from continuing construction operations.

Forms supporting the weight of concrete and construction loads are subject to the stripping limitations imposed for structural concrete. For vertical forms supporting only the lateral pressure of concrete, ACI 347 permits removal after 12 hours at 50F or above for ordinary concrete. This limit conservatively satisfies structural safety under usual conditions. If earlier form removal is desired to meet special finish requirements, it must be demonstrated that safety and curing requirements can be met.

In any case, forms must be stripped so early as to cause damage to the visual quality of any concrete which is to remain in its off-the-form condition. If adhesion between the form face and concrete is greater than cohesion within the concrete, surfaces may scale and corners spall. Research indicates that a compressive strength of about 800 psi (cubic strength) is sufficient to prevent this kind of damage. However, much depends on the over-all quality of site operations; corners and edges can be damaged even when concrete is strong enough to show no structural distress under loading.

For high quality surfaces uniformity in stripping time and curing practices is essential. The longer a form remains in place, the darker the concrete. Even a few hours of difference in stripping time between lifts may cause a color difference that will be visible for years after the job is finished.

Form removal should be planned with regard for possible effects on curing requirements. Some specifications require forms to remain in place for a certain period as part of the curing. If forms are removed before this time is up, measures must be taken immediately after form removal to apply and maintain satisfactory curing. In ho, dry weather, wood forms remaining in place will not provide adequate curing. Such forms can be loosened or removed so that concrete surfaces may be kept moist or coated with appropriate curing agent.

In cold weather, removal of formwork should be deferred or formwork should be replaced with insulation blankets, to avoid thermal shock and consequent crazing of the concrete surface. ACI Committee 303 (11-1) recommends that cooling of architectural concrete surfaces be limited to a gradual drop of 40 deg F in 24 hours in cases where heat has been applied for protection against severe temperatures. ACI 303 also calls attention to cracking danger from thermal shock when cool hydrant water under pressure is used to expose aggregate on retarded surfaces of massive concrete sections.

When stripping forms in the vicinity of a belt course, cornice, or other projecting ornament, begin stripping some distance away from the ornament and work toward it. Thus if there is any tendency for the forms to bind around the ornament the pressure of the forms against projecting corners will be relieved so there will be less chance of spalling sharp edges.

Forms recessed into the concrete require special care in stripping. Wedging should be done gradually and should be accompanied by light tapping on the piece to crack it loose from the concrete. Never remove an embedded form with a single jerk. Embedded wood forms are generally left in place as long as possible so they will shrink away from the concrete. The embedded items should be separate from or loosely attached to the main form so that they will remain in place when the main form is stripped.

When stripping forms for a window opening, cross braces and vertical kick strips should be removed first. Next, take off top and bottom cleats and wedge out the head, using wooden wedges. The wedges should be driven in at one end, forcing the head down and away from the side member. To facilitate stripping, a 45° cut or miter through the sides of the frame is sometimes made when the form is built.

Plaster waste molds should be stripped by someone familiar with the detail. The plaster will usually stick to the concrete, at least in the undercuts, even with proper greasing. It must be carefully cut away with a chisel. If the mold has been made with a layer of colored plaster next to the concrete, the

workman doing the chipping is warned when he has chipped close to the concrete. Plastic, steel or rubber molds can be stripped by introducing compressed air between the concrete and the mold through an opening in the mold for that purpose. Flexible molds are peeled off.

Cleanup and Repair

After forms are stripped, all material to be reused must be thoroughly cleaned of hardened concrete. Some concrete will always adhere to sheathing lumber in spite of thorough oiling or other treatment. A tool made to fit the tongue and groove of matched boards will save time in cleaning the edges of boards.

All nails should be pulled from sheathing boards, plywood, hardwood, and other materials. Never bend nails over by hammering them against the face of the material if reuse for forms is planned. Holes which were bored through sheathing for form ties may be plugged by driving in common corks or foamed plastic and cutting the material off flush with a sharp chisel or fine saw. Patching plaster can also be used to fill small holes.

Cleaned lumber should be sorted by size and length and stored in neat piles. Plywood and fiberboard should be laid flat and out of the sun to keep edges from curling. Forms which are to be reused should be carefully inspected after each use to assure that they have not become distorted or otherwise unable to perform as designed.

Repair of surface defects and patching of tie holes (where specified) is best undertaken soon after form removal. Usually a patch of the same mortar as that in the concrete will be darker than the surrounding concrete. White cement can be mixed with the gray to produce a patch that will blend with the surrounding concrete. About 20 percent white is usually enough. To be sure of color matching, several trial mixes should be made, cured, and allowed to dry for comparison. A leaner mix will also produce a lighter color. Placing a plastic sheet over a patch helps cure the material to a better color match.

SECTION IX: CONCRETE ADMIXTURES

Page	119	Concrete Admixtures
Page	119	Air-Entrainment Agents
Page	119	Water Reducing Agents
Page	120	Accelerators and Retarders
Page	120	Pozzolans

Trainee Section Objectives

1. To learn different types of admixtures in concrete.
2. To describe the effects of various admixtures in placement, consolidation, and finishing concrete.

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Concrete Admixtures

The term admixture refers to the various chemicals that are added to fresh concrete for a variety of reasons. Admixtures mixed in fresh concrete are used to modify the properties of fresh concrete to:

- Increase workability without increasing water content and weakening the concrete.
- Retard or accelerate the setting time.
- Reduce segregation.
- Improve pumpability.
- Reduce the rate of slump loss.
- Reduce bleeding.

Reasons for admixtures to modify the properties of hardened concrete include:

- Reduce the heat generated by hydration.
- Increase early strength gain.
- Increase resistance to severe conditions of exposure.
- Increase overall strength.
- Decrease permeability.
- Increase the bond to reinforcement materials and to increase the bond between new and old concrete.
- To inhibit corrosion of reinforcement materials.

Types of Admixtures

Admixtures are grouped in families according to the purpose they serve in the concrete. The five groups listed below are the most common additives.

1. Air Entraining Agents
2. Plasticizers
3. Accelerators
4. Retarders
5. Pozzolans

Air Entraining Agents

Air-entraining admixtures should always be required when the concrete is subjected to cycles of freezing and thawing, particularly where the use of de-icing salts is anticipated. Applications such as highway pavements, garage floors, and sidewalks placed in cold climates are good examples. Resistance to the freeze-thaw cycle is brought about by the presence of billions of microscopic bubbles throughout the cement paste portion of the concrete mix. These bubbles allow for expansion and contraction of moisture present in the concrete during freezing and thawing cycles.

Some air-entraining materials are:

- Alkali salts of sulfate and 120 sulfonated organic compounds.
- Water soluble soaps of resin acids and animal and vegetable fatty acids.
- Natural wood resins such as rosin.

Air-entrainment of concrete may be accomplished two ways -- either mixed in during the manufacture of the cement or added during the mixing process of the concrete (called batching). Adding air-entraining agents during batching is recommended due to the wide variety of concrete mixes and varying conditions at the placement site.

The lubricating effects of air-entrainment agents greatly improve the workability of high aggregate content concrete. This is accomplished by reducing the friction between aggregate particles. Air-entrainment will also minimize bleeding and segregation.

Air-entrainment may have an effect on the strength of concrete, especially concrete with high cement content. If water content and fine aggregate amounts are adjusted, strength loss will be minimum and more than offset by improved workability and durability.

Water Reducing Admixtures

As their name indicates, these admixtures reduce the quantity of mixing water necessary to produce concrete of a given consistency. Also called "plasticizers", they maintain workability while reducing the amount of water normally required. Slump can be increased without the addition of water making placement easier and maintaining the mix strength. By maintaining slump with a water reducing admixture, a lower water-cement ratio is obtained. The lower ratio allows the hardened concrete to have increased compressive strength, reduced permeability, and when used with air-entrainment, a greater resistance to cracking from freezing and thawing cycles.

The most common materials used as water reducing admixtures are lignosulfunic acid and their salts, and hydroxylated carboxylic acids and their salts. These admixtures are used in very small amounts, usually less than 0.3% of the weight of the cement, and must be very carefully controlled.

The need for careful mixing control usually requires that most plasticizers be mixed at the plant according to project specifications. Most on the job mixing of plasticizers is only done in special circumstances, such as mixing small amounts of grout or concrete for special project applications.

High-range, water-reducing admixtures called "super plasticizers" greatly reduce the friction between cement particles resulting in increased slump without use of additional mixing water.

Accelerators and Retarders

Set retarding admixtures are closely related to water-reducing admixtures. The same materials often serve as both water-reducing and set-retarding admixtures. These materials can be modified to serve one or both purposes. Retarders are used primarily to slow the setting of concrete curing hot weather and maintain workability during placement. Often set retarders are used to keep concrete workable between lifts to avoid cold joints.

Accelerators are added to concrete to improve strength of concrete at early ages and to speed up setting during cold weather. Calcium chloride is the oldest and most common accelerator used. Other accelerating materials include sodium silicate, triethanolamine, and high alumina cement. Calcium chloride should not be used in reinforced concrete due to the increased possibility of corrosion of the reinforcing steel.

When using accelerators for rapid strength gain during hot weather, finishing must be accomplished very quickly due to the rapid set of the mix. Other considerations with accelerators is the likelihood of shrinkage cracking from the increased heat of hydration.

Pozzolans

Pozzolans may be either manufactured or found in natural form. Manufactured pozzolans are crushed and ground blast furnace slag and fly ash. Natural pozzolans are volcanic ash and pumicite. Pumicite can usually be used directly without any processing. Some other natural pozzolans that need processing are calcined or burnt shales and clays and siliceous sedimentary rocks such as opaline chert. These other natural pozzolans must be crushed and ground into fine powders for use.

Pozzolans react with the hydrated lime formed during hydration of the concrete to increase the tensile and compressive strength, lower the permeability and improve resistance to salts. The finely ground pozzolan particles also help reduce segregation and bleeding of fresh concrete.

The ability of pozzolans to lower the heat of hydration and offer increased resistance to salts, make their use most common in mass concrete structures such as dams and in structures that are exposed to severe salt concentrations like sea water.

One detrimental affect of pozzolan is the need to increase the amount of air-entrainment agent to maintain the desired air content. Other general affects are listed below:

- The need for less cement in the mix as the pozzolan is used as a replacement usually ranging from 10 to 30%
- Less heat of hydration, especially in mass concrete due to the use of less portland cement.
- Increased workability of lean mixes due to added fines. Bleeding and segregation is also reduced as some pozzolans, particularly fly ash, require less mixing water for the same consistency.
- For lean mixes the strength is increased with the use of some pozzolans. Strength gain is slower and longer curing time is necessary, however, some pozzolans give compressive strengths that are higher that plain concrete after one year.
- Some pozzolans increase drying shrinkage and require moist curing, but with fly ash, shrinkage is decreased due to the use of less mixing water.
- Salt resistance is improved by most pozzolans particularly those high in silica.
- Reduction of cracking.

Page 122 Sawing Concrete

Trainee Section Objectives

1. To demonstrate proper maintenance procedures for a concrete saw.
2. To demonstrate proper operating procedures for a concrete saw.
3. To identify and use different types of blades for a concrete saw.

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Sawing Concrete

Two major uses of concrete saws are cutting contraction joints in slabs and pavements, and sawing the perimeter of areas for concrete work.

When sawing contraction joints in slabs, timing is the most critical factor. Sawing must begin as soon as possible to control cracking stresses, but the concrete must be hard enough to not damage the surface. When the weather is hot and dry, sawing can begin within 4 to 12 hours after finishing. During cooler weather sawing must be delayed up to 24 hours, or until surface damage does not occur. Other factors affecting timing of sawing are the time of day when the concrete was placed, type of concrete mix, use of admixtures, and the type of curing used.

To begin sawing contraction joints, make a test cut to check for proper sawing time. A slight ravelling at the cut will indicate proper timing. Surface damage such as depressions from the saw indicates the concrete is not ready.

Width and depth of cuts for contraction joints vary greatly. Slab size, thickness, and the use of joint fillers are some of the determining factors. The depth of cut for contraction joints should be one-fifth to one-fourth of the slab thickness. Joint widths for floors and slabs not to be sealed are usually $1/8$" to $3/16$". For pavements where joint sealers are used, widths of $1/4$" or more are required.

Spacing of joints for sidewalks is normally equal to the width of the walk (e.g. 5 foot walks would have contraction joints 5 feet apart). In slabs, floors, and driveways 20 feet should be maximum spacing.

Sawing speed will be determined by factors such as:

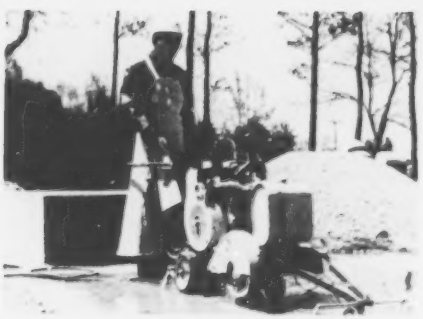
- Size of sawing equipment.
- Depth and width of cut.
- Hardness of aggregate and age of concrete.
- Type of blade used.

LABORERS-AGC TRAINING TIPS

No. 6

TRAINEE INFORMATION PROFILE SERIES

CONCRETE SAWS



This manual is designed as a supplement to the video "CONCRETE SAWS" and to the hands-on training you will receive at your local training site.

We have highlighted the main points to remember. Your instructor will see that you get additional information.

When you complete your training, this book will serve as a reminder of what you've learned. If you put all the information received during your training into practice on the job, you will benefit your Union, your Employer and most of all YOURSELF.

Concrete saws range from 6 to 60 horsepower, and are used to cut contraction joints in highways, to control cracking of concrete, and to cut smooth borders before concrete is hammered out to control the breaking of the concrete.

Most models and sizes have the same basic features:

- usually a 4-cycle gasoline powered engine
- an air filter - a dry element or an oil-bath type
- a line guide - to help you saw to a chalk or paint line. There's usually a front guide and a rear guide.
- A blade depth control. On some models a handwheel is turned to lower and raise the blade in and out of the cut.
- A blade guard, to protect against concrete particles or blade fragments, should a blade come apart.
- A water feed, which provides jets of water on both sides of the diamond blade to keep it cool.
- a circular blade, either the diamond or the abrasive blade.

BLADES

Abrasive blades are used to cut asphalt or green concrete with a soft aggregate. The abrasive blades wear away as they cut.

Diamond blades last much longer. They're used on cured concrete or green concrete with aggregate too hard for the abrasive blade to cut. Diamond blades are expensive. Always handle them carefully. Never cut without using water; diamond blades can burn up in a matter of seconds.

GETTING STARTED

Always inspect your equipment before you take it out on the job site. Follow the standard maintenance procedures for small gas engines:

- Check the oil level - If it is low, add non-detergent oil to the crankcase. Use 30-weight in warm weather, 20-weight in cold weather. Newer engines require high detergent oil, so refer to instruction plate.
- Check the gasoline level - If low, add regular gasoline to the tank.
- Check the air filter - If necessary, tap the dry-element type to knock out loose particles. For the oil-bath type, clean out the dirty oil, and re-fill with new oil to the proper level.
- Check the tension of the belts, and tighten according to specifications.
- Some models need to be greased daily.
- Check the water level in the battery.

When you have finished fueling and routine maintenance, move away from the fueling area and check to make sure the engine starts and is in good working order before you move to the work area.

As it is with most jobs you do, planning is important when you intend to use the concrete saw. You must know what is to be cut, where, and how deep. Your labor foreman will give you this information.

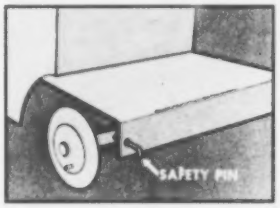
Make sure you bring the proper blades, tools, and equipment including spare plugs and enough gas to do the job. If you're going to use a diamond blade, you must have a water supply.

Safety equipment should include gloves, goggles and ear protection. If you are going to use an abrasive blade without water you will also need a respirator.

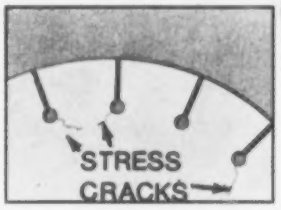
Make guide lines for cutting, using chalk, crayon, or spray paint. In some situations, chalk lines will wash away when using water, and you may find that crayon or spray paint works best.

INSTALLING THE BLADE

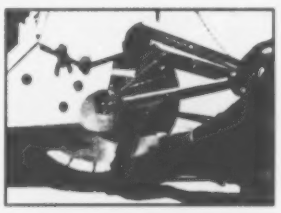
Before installing the blade, first make sure the ignition switch is OFF or the spark plugs are disconnected. As an added precaution, some models have a safety pin which must be inserted in the arbor shaft before installing the blade.



Then, raise the saw as high as possible, remove the holding nut and flange, and clean the shaft and flanges. Inspect the blade before you install it, especially used blades. On diamond blades, look for stress cracks or marks. The danger here is, if the stress cracks meet, a piece of the blade could break off and hit you or a fellow worker. Always check the RPM rating on the blade, and compare it to the RPM rating of the engine. Never use a blade that has a lower rating; it can come apart.



When you install the blade, make sure it is aligned properly. Slip on the outer flange. It should also fit securely. Hand-tighten the holding nut, and then wrench-tighten with the tool designed for the job. The blade should now be held firmly in place.



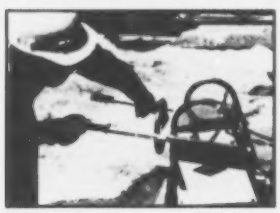
READY TO CUT

Lower the blade guard and lock it in place. If

the saw has a safety pin in the shaft, remove it. Now, position the saw over the cut line. You will have to align the front guide, the blade, and rear guide. All three of these must be accurately aligned to maintain a constant, straight cut, to prevent excessive blade wear, and to keep the blade from binding.

Choke and start your engine While the engine is warming up, open the water supply, and turn on the water pump. Water should be sprayed on both sides of the blade for best cooling results.

When you are satisfied that the engine is warm, and that you have an adequate flow of water, put on your safety goggles and ear protection, and open the throttle all the way. Caution! Always saw at FULL throttle. Never attempt to saw at a slower engine speed.

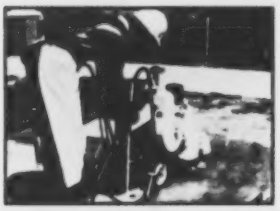


Now, turn the depth control and slowly lower the blade. Never ram the blade down. On models that have automatic depth control features, you would set the depth counter to zero when the blade touches the surface and would then lower the blade until the counter showed the desired depth.

On manual models, such as this, you must estimate the depth of the cut. When you've reached the desired depth, lock the depth control at that position. The locking device will help keep the blade from riding up out of the cut.

Move forward slowly along the line, maintaining a steady feed. These saws tend to creep to the right or left, so you'll find that a slight countering pressure on the handle maintains alignment. If the machine begins to chatter or vibrate excessively, you're feeding too fast. Slow down.

Always keep people away from the front of the machine. This is the danger area if a blade comes apart. If you have trouble making a deep cut, make two passes, the first at a shallower cut. You can check the depth manually



in several ways. Perhaps the easiest and safest way is with a stick or lath, notched at grade. Due to the mixture of concrete dust and water, the area around the saw can become very slippery, so watch your step.

If the blade stalls or hangs-up in the cut, stop

the engine immediately and raise the blade completely out of the cut and check for damage before re-starting. If you are finished cutting, turn off the water pump before you shut off the water supply. Never run the pump dry and never choke the engine to stop it; use the ignition switch.

When you cut with abrasive blades, you do not need the water spray. Water can be used, however, for instance, to eliminate sparks if you had to cut in an area where there was combustible material, or simply to reduce the dust problem.

When you use the concrete saw without water, you must use a respirator. Concrete dust can seriously injure your lungs. The dust can also keep the machine from operating at peak performance. Some models have a pre-cleaner in the air-filter system which must be checked and cleaned frequently, under severe conditions, as often as once every half hour.

SHUT DOWN

When you've finished cutting, remove the blade, and clean the saw. Blades should be protected at all times, either in cartons, on pegs, or in carrying cases.

When cutting with the concrete saw, give it and the job at hand your full attention. Laborers who plan a job properly, and operate the concrete saw safely and efficiently, will always be in demand.

KEY POINTS TO REMEMBER

- WEAR GOGGLES AND EAR PROTECTION AND WHEN YOU'RE CUTTING WITHOUT WATER, A RESPIRATOR MUST BE WORN TO PROTECT AGAINST DUST.
- CHECK RPM RATING ON THE BLADE AND THE SAW.
- BEFORE INSTALLING BLADE MAKE SURE THE IGNITION SWITCH IS OFF.
- ALWAYS CUT AT FULL THROTTLE.
- WATER MUST BE USED WHEN CUTTING WITH A DIAMOND BLADE.
- ALWAYS KEEP PEOPLE AWAY FROM THE FRONT OF THE MACHINE.
- NEVER RAM THE BLADE DOWN. LOWER IT SLOWLY.
- MAINTAIN A STRAIGHT CUT. A BLADE CAN BIND AND SHATTER IF YOU DON'T.
- IF THE BLADE STALLS OR HANGS UP IN THE CUT, STOP THE ENGINE IMMEDIATELY, AND RAISE THE BLADE COMPLETELY OUT OF THE CUT AND CHECK FOR DAMAGE BEFORE RE-STARTING.
- INSPECT FOR STRESS CRACKS.

General Occupational Safety and Health Regulations
Concrete Saws

ITEM	REFERENCE
Personal Protective Equipment (Head, Foot, Hand, Hearing, Eye/Face, Respiratory)	29CFR 1926.28
Hazard Communication	29CFR 1926.59
General Safety and Health Requirements	29CFR 1926.20
Safety Training and Education	29CFR 1926.21
Tools - Hand and Power, General Requirements	29CFR 1926.300
Occupational Noise Exposure	29CFR 1926.52
Flammable and Combustible Liquids	29CFR 1926.152
Fire Protection	29CFR 1926.150
Fire Prevention	29CFR 1926.151
Gases, Vapors, Fumes, Dust and Mists	29CFR 1926.55

Additional standards may apply when used in special construction activities such as demolition or tunnels and shafts.

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Page 124 Concrete Repair

Trainee Section Objectives

1. To demonstrate competency at preparing the surface for repair.
2. To demonstrate competency with patch material placement.
3. To identify the best method for patching various types of concrete deterioration.

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Concrete Repair

Many factors influence the deterioration of concrete structures. Concrete damage can be caused by severe weather conditions, the use of de-icing salts, exposure to sulfate action, corrosion of reinforcing steel, exposure to heavy truck traffic on pavement, and poor construction practices.

There are many types of repair necessary in both old and newly placed concrete. In new construction repairs could include honeycomb, air and rock pockets, damage from form removal, she-bolt and wall tie holes, and unevenly finished surfaces. Repairs for old concrete include pavement spalls and scaling, cracks, poorly constructed joints, frost damage, and de-lamination caused by rusting of reinforcement.

The type of repair method used will be determined by the extent of the damage and whether the repair is for structural or cosmetic purposes. Structural repairs are necessary repairs that maintain the load bearing capacity of a structure and cosmetic repairs restore the appearance of a structure. Some types of repair include:

Pavements
- Full depth and partial depth patching.
- Surface overlays

Cracks
- Large cracks can be mortar filled.
- small cracks can be injected with epoxy resign by pressure or gravity.

Spalls
- Large spalls are repaired by concrete replacement.

After determining the extent of damage to the concrete structure and choosing a repair method, the next step is to prepare the surface for repair.

Surface Repair

Proper surface preparation for the type of repair is critical to the success of the repair. Regardless of the type of repair to be performed the first step is the removal of all loose and disintegrated concrete form the surface. Light chipping guns should be used instead of large breakers to prevent damaging solid concrete and reinforcing steel. Removal should continue until no dull concrete surfaces remain and the entire area looks "bright". Sawing around the edges of the repair area of slabs and pavements is recommended as broken or feathered edges are likely to crack or peel away from the old surface. If possible, angle the saw cut to make the patch area smaller at the top to hold the patch material in place.

Reinforcing steel exposed during concrete removal must be clean and free of rust. When doing full depth pavement repair, dowel bars must be installed into the old concrete surface to provide adequate load transfer. If additional reinforcing is required in the repair area it should be securely tied to existing steel or to bolts anchored by epoxy resins. If the reinforcement will be covered by an epoxy material it must be dry and cleaned to bright metal by sandblasting or shotblasting.

After removal of all old, deteriorated concrete has been completed the surface must be thoroughly cleaned. Cleaning should be done with high-pressure water spray to remove all particles and residues left from removal. A final cleaning should be done immediately before placing the patch material to assure a good bond.

When placing concrete or mortar patches the concrete surface should be moist, but not wet. Concrete can be kept moist by the use of burlap or curing blankets. Any excess water should be removed with compressed air.

Concrete Replacement

Concrete replacement is used for full-depth pavement repairs, large honeycomb areas in newly placed concrete, and the repair of large deteriorated areas of dams and other structures. The replacement concrete must be batched the same as the original mix for the structure. Some forming is usually required for large concrete replacement repairs such as edges of pavements and on vertical surfaces. The forms must fit tightly to the old concrete to prevent mortar loss and to ensure an eye-pleasing patch.

The old concrete should be covered with a $1/8$" coating of mortar, sprayed or brushed onto a damp surface, immediately followed by placement and consolidation of the concrete. Slabs and pavements should be finished to match the existing surfaces.

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Overlays

Bonded overlays are used to repair scaled pavements and other flat slabs where the surface has scaled due to the use of de-icing salts or the lack of air-entrainment. The newest method of surface preparation for overlays is shotblasting, where steel shot is used as an abrasive much like sandblasting, except the equipment recovers and re-uses the steel shot and vacuums up the old concrete particles and the dust. After removing the scaled concrete, the surface should be washed with a water spray. As with other repair methods the surface should be damp but not wet. Brush a grout mix onto the surface with a coarse broom and follow immediately with the surface topping material. If the bonding grout is made up of epoxy materials, the prepared surface of the old concrete must be dry when brushing on the bond coat.

The most important factor influencing the quality of the overlay is to maintain a 1" to 2" slump of the topping material. This topping material is then screeded with a vibrating screed to the desired elevation. Do not bull float thin overlays as this tends to break the bond between the new topping and the old concrete. As the overlay sets enough to support a persons weight with only a slight indentation, float carefully and finish to match surrounding concrete surfaces. Joints in the old concrete must be duplicated in the overlay and also along the adjoining slabs so the overlay material can move freely. Stress from the overlay material bonding to the adjoining slabs could cause failure of the topping material.

Curing of the overlay is important to prevent shrinkage of the topping material and should be started immediately following finishing. Misting the overlay is recommended for several hours, followed by the application of a quality curing compound.

Many different overlay topping materials are used for bridge decks, parking ramps, parking lots, and other pavements. Some of these are:

- Latex modified portland cement. Latex is mixed with water, portland cement, and sand for thin, feather edged overlays.

- Polymer concrete with no portland cement. Polymer concrete is impermeable to water, de-icing salts, and chemicals that accelerate corrosion of reinforcement. Polymer concrete is very expensive and needs special equipment for placement. Advantages include very thin overlays of only $1/2$" to $3/4$" and a curing time as little as 2 hours. Curing time is very short and polymer concrete overlays can be opened to traffic in 6 to 10 hours, depending on ambient temperature.

- Epoxy mortar, or epoxy concrete, consists of epoxy resin and a hardener that, when mixed together, form a tough, plastic solid which provides excellent bonding between materials. First an epoxy bond coat is applied to the prepared surface, followed by the epoxy mortar or concrete. The topping is then screeded and trowelled to the desired finish. The epoxy bond coat can also be used as a bonding agent for patching and full depth repairs.

Crack and Joint Repair

As with other types of repair, cracks and joints must be cleaned before repair can begin. Wire brushing is the best way to prepare a crack and the surrounding wall surface for injection of the repair material. Grinding or chipping may fill the crack with dust which would prevent proper injection and bonding. In the case of resealing old joints be sure all the old joint sealer or filler is removed. The use of picks or similar tools may be required. The surfaces of joints should be cleaned and roughened by sandblasting or shotblasting to provide the desired bond.

Several factors determine what type of material to use for crack repair. Is the crack active or dormant? That is, does the crack continuously get wider or narrower? Cracks may get wider from settlement, or change widths from load changes or heaving soils. Other factors that determine the type of material used are the width of the crack; whether the crack is wet or dry; or, if the repair being made for structural integrity or for waterproofing purposes.

Expansion joints and longer, active cracks can be filled with the same elastomeric materials. These materials remain slightly plastic and allow movement of the concrete without breaking the bond. This is especially important in pavements to prevent moisture and deicing salts from deteriorating the concrete adjacent to expansion, construction, and control joints. Materials used for filling joints or cracks are known as joint fillers or sealants, or caulking compounds. Some of these materials are applied hot, some cold.

- Mastics are usually low melting point asphalts containing some type of filler material. They should be used where only very small movement of the concrete is expected as they harden with time.

- Hot-applied thermoplastics set by the release of a solvent, or breaking of an emulsion when exposed to air. These materials may be acrylic, vinyl, or modified butyl and can be applied at normal temperature or by heating to not over 120°F.

- Chemically curing thermosetting sealants include polysulfide, silicone, urethane, and epoxy base materials. These materials set by a chemical reaction after mixing of a two component liquid system. These materials can be used in horizontal and vertical applications where considerable movement is expected.

The field molded materials listed here are usually applied by pouring, troweling, or by caulking-type guns.

Repair of small cracks should be done by injecting a resin to bond the surfaces. If the crack is dry, epoxy resin is the best choice. Epoxy bonds well and provides good structural strength. For wet or leaking cracks a polyurethane resin should be used. Polyurethanes have good adhesion wet or dry, they cure rapidly by varying the mix ration of the two components, but don't restore structural strength as well as epoxies do.

Before injecting resins a cap must be applied to a clean, sound surface along the crack. This prevents the resin from leaking out during injection. Be sure the area adjacent to the crack is free of dust so the cap material bonds well to prevent resin leaks. Injection ports should be spaced from 8 to 26 inches apart, depending on the width of the crack. Place these ports at wide spots in the crack, or where two cracks intersect. Injection equipment will determine the type of port to be used. Holes can be drilled and plastic pipe nipples can be inserted, or the parts can be held in place by the cap material. A washer installed in the cap material can also be used as a seat for the injection nozzle. The cap material should be a gel-type epoxy with a 1 to 3 hour cure time. Massage the gel over the crack to assure a good bond. The cap should be at least 1/8" thick and 1 to 2 inches wide.

Injection should begin at the widest point of the crack and continue until you get back pressure. If resin bleeds out of adjacent ports before desired pressure is attained, plug the port and continue injection until back pressure is built up. If the cap develops a resin leak injection should stop until the resin sets up or the leak can be plugged.

After the epoxy resin has cured, the entry ports can be removed with a sharp chisel and hammer. If the surface appearance is not important the cap can be left in place. If cap removal is required it can be accomplished with a rotary grinder.

Safety precautions must be followed when working with concrete repair materials and injection resins. Most of these compounds are hazardous materials. Avoid eye and skin contact by wearing protective glasses and clothing, especially rubber or plastic gloves. Always use ventilation when working with epoxy or polyurethane resins as they could cause eye, nose, or throat irritation. Keep water on hand to rinse areas that come in contact with these materials. Dispose of all containers and waste materials properly.

Appendices

Pages 1 - 12 Appendix A: Glossary of General Cement and Concrete Terms

Pages 13 - 15 Appendix B: Glossary of Terms For Concrete Tools and Equipment

Pages 16 - 24 Appendix C: Glossary of Terms For Concrete Formwork and Accessories

APPENDIX A: GENERAL CEMENT & CONCRETE TERMS

The efficiency of any communications system lies in the ability of all concerned to understand the terminology used. Cement and concrete technology continues to increase in scope; consequently, it is important to stay abreast of the terms related to this rapidly expanding field. Because the classification of people involved in cement and concrete, either in manufacture or use, is so wide, a glossary should be one that can be understood whether the reader is architect, engineer, contractor, workman, supplier of materials, or one of the many others involved.

Since the range of individuals who can benefit from a glossary is so wide, this is an attempt to make definitions as basic as possible. It is not the intent of this manual to cover every term in every classification, but those which are most used or misused.

Abrasion Resistance Resistance of a surface to being worn away by a friction or rubbing process.

Absolute Volume The volume of an ingredient in its solid state, without voids between individual pieces or particles, in the case of fluids, the cubic content occupied. In concrete, it is the actual volume occupied by the different ingredients determined by dividing the weight of each ingredient in pounds by its specific gravity time weight of one cubic foot of water in pounds.

Example: Absolute Volume of one sack of cement equals:

$$\frac{94 \text{ lbs.}}{3.15 \times 62.4} = 0.478 \text{ cubic feet}$$

Absorbed Moisture Moisture mechanically held in a material. In aggregates, that water which is not available to become part of the mixing water is designated "absorbed" water.

Absorption The process by which water is absorbed. The amount of water absorbed under specific conditions, usually expressed as percentage of the dry weight of the material.

Accelerator An admixture which, when added to concrete, mortar, or grout, increases the rate of hydrations of the hydraulic cement, shortens the time of set and increases the rate of hardening or strength development.

Amiabatic Curing The maintenance of ambient conditions during the setting and hardening of concrete so that heat is neither lost nor gained from the surroundings of the concrete.

Admixture A material other than water, aggregates, and portland cement (including air entraining portland cement and portland blast furnace slag cement), that is used as an ingredient of concrete, and is added to the batch immediately before or during the mixing operation.

Absorbed Water Water held on surfaces in a material by either physical and/or chemical forces.

Air Content The amount of entrained or entrapped air in concrete or mortar, exclusive of pore space in aggregate particles, usually expressed as a percentage of total volume of concrete or mortar.

Air Entraining Agent An addition for hydraulic cement, or an admixture for concrete or mortar which entrains air in the form of minute bubbles in the concrete or mortar during mixing.

Alkali-aggregate Reaction The chemical reaction in concrete or mortar between alkalies (sodium and potassium oxides) from portland cement or other sources and certain constituents of some aggregates, primarily certain phases of silica, which causes deterioration in the form of strength loss, excessive expansion, and cracks in the concrete or mortar.

Aluminous Cement A hydraulic cement in which the principal constituents are calcium aluminates, instead of calcium silicates which comprise the major ingredients of portland cement. (See calcium aluminate cement.)

Autoclave A chamber in which an environment of steam and high pressure is produced. Used in the curing of concrete products and in the testing of hydraulic cement for soundness.

Bag (of cement)(See Sack)

Barrel (of cement) A unit of weight for cement: 376 lbs. net, equivalent to 4 U.S. bags of portland cement.

Blaine Fineness The fineness of granular materials such as cement and pozzolans, expressed as total surface area in square centimeters per gram, determined by the Blaine air-permeability apparatus and procedure.

Blast Furnace Slag A non-metallic waste product developed in the manufacture of pig iron, consisting basically of a mixture of lime, silica and alumina, the same oxides that make up portland cement, but not in the same proportions or forms. It is used both in the manufacture of portland blast furnace slag cement and as an aggregate for lightweight concrete.

Bleeding A form of segregation in which some of the water in a mix tends to rise to the surface of freshly placed concrete. Known also as water gain.

Bond Adhesion of concrete or mortar to reinforcement, or to other surfaces against which it is placed. The adhesion of cement paste to aggregate.

Bush-hammer A tool having a serrated face, as rows of pyramidal points, used to develop an architectural finish for concrete surfaces.

Calcareous Containing calcium carbonate or, less generally, containing the element calcium.

Calcine To alter composition or physical state by heating.

Calcium Aluminate Cement The product obtained by pulverizing clinker consisting essentially of hydraulic calcium aluminates resulting from fusing or sintering a suitably proportioned mixture of aluminous and calcareous materials.

Capillary Space In cement paste, any space not occupied by anhydrous cement or cement gel. (Air bubbles, whether entrained or entrapped, are not considered as part of the cement paste.)

Carbonation Reaction between the products of portland cement and carbon dioxide to produce calcium carbonate.

Cellular Concrete A lightweight product consisting or portland cement, cement-pozzolan, cement-sand, lime pozzolan, or lime-sand pastes, or pastes containing blends of these ingredients and having a homogenous void or cell structure, attained with gas-forming chemicals or foaming agents. For cellular concretes containing binder ingredients other than or in addition to portland cement, autoclave curing is usually employed.

Cement Content A quantity of cement contained in a unit volume of concrete or mortar, ordinarily expressed as pounds, barrels, or bags per cubic yard.

Cement Gel The colloidal (glue like) material that makes up the major portion of the porous mass of which hydrated cement paste is composed.

Cementitious Having cementing properties.

Coarse Aggregate Naturally occurring, processed or manufactured, inorganic particles in prescribed gradation or size range, the smallest size of which will be retained on the No. 4(4.76 mm) sieve.

Coefficient of Thermal Expansion Change in unit length per degree change of temperature.

Cold Joint A visible lineation which forms when the placement of concrete is delayed. The concrete in place hardens prior to the next placement of concrete against it.

Compressive Strength The measured resistance of a concrete or mortar specimen to axial loading expressed as pounds per square inch (psi) of cross-sectional area. The maximum compressive stress which material, portland cement, concrete, or grout is capable of sustaining.

Concrete A composite material which consists essentially of a binding medium within which are embedded particles or fragments of a relatively inert filler. In portland cement concrete, the binder is a mixture of portland cement and water; the filler may be any of a wide variety of natural or artificial, fine and coarse aggregates; and in some instances, an admixture.

Consistency The degree of plasticity of fresh concrete or mortar. The normal measure of consistency is slump for concrete and flow for mortar.

Consolidation Compaction usually accomplished by vibration of newly-placed concrete to minimum practical volume, to mold it within form shapes and around embedded parts and reinforcement, and to eliminate voids other than entrained air.

Construction Joint The contact between the placed concrete and concrete surface, against or upon which concrete is to be placed and to which new concrete is to adhere, that has become so

rigid that the new concrete cannot be incorporated integrally by vibration with that previously placed. Unformed construction joints are horizontal or nearly so.

Corrosion Inhibitor A chemical compoune, either liquid or powder, that effectively decreases corrosion or steel reinforcement in hardened concrete. Usually used in very small concentrations.

Cure Method of maintaining sufficient humidity and proper temperature for freshly placed concrete to assure proper hydration of the cement, and proper hardening of the concrete.

Dampproofing Treatment of concrete or mortar to retard the passage or absorption of water by use of a suitable admixture or treated cement.

Density Weight per unit volume

Dispersing Agent An admixture capable of increasing the fluidity of pastes, mortars, or concretes by reduction of interparticle attraction.

Drying Shrinkage A decrease in the volume of concrete upon drying.

Dry Rodded Weight The weight of dry aggregate rodded into a cylindrical container of diameter approximately equal to the height, each of 3 layers rodded 25 times, and the excess aggregate struck off level with the top of the container.

Durability The ability of concrete to resist weathering action, chemical attack, and abrasion.

Efflorescence A crystalline deposit of soluble salts, usually white in color, appearing on the surfaces of masonry, stucco or concrete.

Elastic Shortening In prestressed concrete, the shortening of a member which occurs on the application of forces induced by prestressing.

Entrained Air (See air entrapment) Microscopic air bubbles intentionally incorporated in mortar or concrete, to improve workability and durability (especially resistance to freezing and thawing).

Entrapped Air Air in concrete which is not purposely entrained. Entrapped air bubbles are normally much larger and more irregular than entrained air bubbles.

False Set The rapid development of rigidity in a mixed portland cement paste, mortar, or concrete without the evolution of much heat. This rigidity can be dispelled and plasticity regained by further mixing without addition of water. Premature stiffening, and rubber set are terms referring to the same phenomenon, but false set is the preferred term.

Fine Aggregate Aggregate passing the 3/8 in. sieve and almost entirely passing the No. 4 (4.76 mm) sieve and predominantly retained on the No. 200 (74 micron) sieve (ASTM C 125).

Fineness Modulus An index of fineness or coarseness of an aggregate sample. An empirical factor determined by adding total percentages of an aggregate sample retained on each of a specified series of sieves, and dividing the sum by 100.
Note: U. S. Standard sieve sizes are used: No. 100, No. 50, No. 30, No. 16, No. 8, and No. 4, and 3/8 in., 3/4 in., 1 1/2 in., 3 in., and 6 in..

Flash Set The rapid development of rigidity in a mixed portland cement paste, mortar, or concrete usually with the evolution of considerable heat, which rigidity cannot be dispelled nor can the plasticity be regained by further mixing without addition of water. Also referred to as quick set or grab set.

Flexural Strength A property of a solid that indicates its ability to withstand bending.

Fly Ash The finely-divided residue that results from the combustion of ground or powdered coal, transported from the firebox through the boiler by flue gases.

Foam Concrete (See cellular concrete)

Gap-Graded Aggregate Aggregate containing particles of both large and small sizes, in which particles of certain intermediate sizes are wholly or substantially absent.

Gas Concrete (See cellular concrete)

Gillmore Needle A device used in determining time of setting of hydraulic cement, described in ASTM C 266.

Gradation The sizing of granular materials: for concrete materials, usually expressed in terms of cumulative percentages larger or smaller than each of a series of sieve openings or the percentages between certain ranges of sieve openings.

Grout A fluid mixture of (1) cement, sand, and water or (2) cement and water: the hardened equivalent of such mixtures.

Gunite A term sometimes used to designate dry-mix shotcrete.

Heat of Hydration The quantity of heat expressed in calories per gram, evolved upon complete hydration of portland cement at a given temperature.

Holding Period In the manufacture of concrete products, the period between completion of casting and the introduction of additional heat or steam curing period.

Hydration Formation of a compound by the union of water with some other substance. In concrete it is the chemical reaction between water and the cement.

Hydraulic Cement A cement that is capable of setting and hardening under water due to interaction of water and the constituents of the cement (ASTM 219).

Initial Set A degree of stiffening of the cement and water mixture. This is a degree less than final set and is generally stated as an empirical value, indicating the time in hours and minutes

required for a cement paste to stiffen sufficiently to resist to an established degree the penetration of a weighted test needle. (Refer to ASTM C 191 or C 266 for weight and penetration data.)

Initial Stress In prestressed concrete, the stresses occurring in the prestressed members before any losses occur.

Jacking Equipment In prestress concrete, the device used to stress the tendons.

Jacking Force The temporary force exerted by the jacking device which introduces tension into the tendons.

Jacking Stress In prestress concrete, the maximum stress occurring in a tendon during stressing.

Kelly Ball A device for determining consistency of fresh concrete. It is sometimes used as an alternative to the slump test.

Keene's Cement A finely ground, high density plaster composed of anhydrous, (calcined or "dead burned") gypsum, the set of which is accelerated by the addition of other materials.

Laitance A residue of weak and non-durable material consisting of cement, aggregate, fines, or impurities brought to the surface of overwet concrete by the bleeding water.

Lift Layer of concrete.

Magnetite An aggregate used in heavy weight concrete, consisting primarily of ferrous metaferrite (Fe_3O_4). A black magnetic iron ore with a specific gravity of approximately 5.2 and a Mohs hardness of about 6.

Marl A calcareous clay, containing approximately 30 to 65 percent calcium carbonate ($CaCO_3$), found normally in extinct fresh water basins, swamps, or bottoms of shallow lakes.

Masonry Cement Hydraulic cement manufactured for use in mortars for masonry construction. Normally a blend of two or more of the following materials: portland cement, natural cement, portland-pozzolan cement, hydraulic lime, slag cement, hydrated lime, pulverized limestone, talc, chalk, pozzolan, clay or gypsum; also may include air entraining additions.

Mass Concrete Any large volume of concrete cast in place intended to resist applied loads by virtue of mass. Generally a monolithic structure incorporating a low cement factor with a high proportion of large coarse aggregate.

Mass Curing Adiabatic curing, using sealed containers

Maximum Size Aggregate Aggregate whose largest particle size is present in sufficient quantity to affect the physical properties of concrete; generally designated by the sieve size on which the maximum amount permitted to be retained is 5 or 10 percent by weight.

Mixer Equipment used for mixing or blending the materials used in the manufacture of concrete, grout or mortar.

Mixing Speed Rate of mixer drum rotation or that of the paddles in a pan, open-top, or trough type mixer, when mixing a batch; expressed in revolutions per minute (rpm), or in peripheral feet per minute of a point on the circumference at maximum diameter.

Mixing Time For stationary mixers, mixing time is calculated in minutes from the completion of charging the mixer until the beginning of discharge; for truck mixer, time is calculated in total minutes at a specified mixing speed. The period during which materials are used in a batch of concrete are combined by the mixer.

Modulus of Elasticity A measure of the resistance of material to deformation. The ratio of normal stress corresponding strain for tensile or compressive stresses below the proportional limit of the material; elastic modulus is denoted by the symbol "E".

Moist Room A room used for storing and curing cementitious test specimens. The atmosphere of this room is maintained at a temperature of 73.4+-3.0F or 23.0+-1.7C and relative humidity of at least 98 percent. These facilities must be adequate to continually maintain free moisture on the exteriors of test specimens.

Monolith A plain or reinforced mass of concrete cast as a single integral structure.

Mortar A mixture of cement, sand and water. When used in masonry construction, the mixture may contain masonry cement, or standard portland cement with lime or other admixtures which may produce greater degrees of plasticity and/or durability.

Natural Pozzolan Either a raw or calcined natural material that has pozzolanic propertiesr (e.g., volcanic ash or pumice).

Neat Cement Unhydrated hydraulic cement.

Neat Cement-Paste A mixture of water and hydraulic cement, both before and after setting and hardening.

No-Fines Concrete A concrete mixture in which only the coarse gradation (3/8" to 3/4" normally) of aggregate is used.

Non-agitating Unit A truck-mounted unit for transporting ready-mixed concrete short distances, not equipped to provide agitation (slow mixing) during delivery.

Non-evaporable Water The water in concrete which is irremovable by oven-drying; chemically combined during cement hydration.

Ottawa Sand A sand used as a standard in testing hydraulic cements by means of mortar test specimens. This sand is produced by processing silica rock particles obtained by hydraulic mining of the orthoquartzite situated in open-pit deposits near Ottawa, Illinois; naturally rounded grains of nearly pure quartz.

Overvibration Excessive vibration of freshly mixed concrete during placement causing segregation.

Particle-Size Distribution Particle distribution of granular material among various sizes; for concrete materials normally designated as gradation. Usually expressed in terms of cumulative percentages smaller or larger than each of a series of sieve openings or percentages between certain ranges of sieve openings.

Pea Gravel That portion of concrete aggregate passing the 3/8" sieve and retained on a No. 4 sieve.

Peeling A process in which thin flakes of matrix or mortar are broken away from concrete surface; caused by adherence of surface mortar to forms as forms are removed, or to trowel or float in portland cement plaster.

Pitting Development of relatively small cavities in a concrete surface, due to phenomena such as cavitation or corrosion.

Plane of Weakness The plane along which a structure under stress will tend to fracture; may exist because of the nature of the structure and its loading, by accident, or by design.

Plastic A condition of freshly mixed concrete, mortar or cement paste indicating that it is workable and readily remoldable, is cohesive, and has ample content of fines and cement but is not over wet.

Plastic Consistency Condition in which concrete, mortar, or cement paste will sustain deformation continuously in any direction without rupture.

Plasticity That property of freshly mixed concrete, cement paste or mortar which determines its ease of molding or resistance to deformation.

Plasticizer A material that increases the plasticity of fresh concrete.

Porosity The ratio of the volume of voids in the material to the total volume of the material, including the voids, usually expressed as a percentage.

Portland Blast-Furnace Slag Cement (ASTM C 205) The product obtained by intimately ingrinding or initiate and uniformly blending a mixture of granulated blast-furnace slag and portland-cement clinker.

Portland Cement (ASTM C 150) The product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates.

Portland-Pozzolan Cement (ASTM C 340) The product obtained by intimately ingrinding a mixture of portland-cement clinker and pozzolan, or an intimate and uniform blend of portland cement and fine pozzolan.

Post-tensioning A method of prestressing concrete in which the tendons are tensioned after the concrete has hardened.

Pozzolan (ASTM 340) A siliceous, or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Precast A concrete member that is cast and cured in an area other than its final position.

Prepacked Concrete Concrete manufactured by placing clean, graded coarse aggregate in a form and later injecting a portland cement-sand grout, under pressure, to fill the voids.

Prestressed Concrete Concrete in which stresses have been introduced which are opposite in sense to those that the structural member will be expected to carry during its use.

Pretensioning A method of prestressing reinforced concrete in which the steel is stressed before the concrete has hardened and restrained from gaining its unstressed position by bond to the concrete.

Proportioning Selection of proportions of material for concrete to make the most economical use of available materials to manufacture concrete of the required strength, placeability, and durability.

Pumping (of Pavement) The ejection of mixture of water and solid materials such as clay or silt along cracks, transverse or longitudinal joints, and along pavement edges caused by downward slab movement activated by the passage of heavy loads over the pavement after free water has accumulated in or on the subbase, subgrade or base course.

Rebound Wet shotcrete or sand and cement which bounces away from a surface against which pneumatically applied mortar is being projected.

Refractory Concrete Concrete having refractory properties and suitable for use at high temperature. Calcium-aluminate cement and refractory aggregates are normally used for the manufacture of this product.

Reactive Aggregate (See alkali-aggregate reaction)

Reinforced Concrete

A. Concrete in which steel bars have been placed to sustain the tensile stresses.
B. Concrete in which reinforcement, other than that provided for temperature changes for shrinkage, has been embedded in such a manner that the two materials act together in resisting forces.

Retardation Delaying the hardening or strength gain of fresh concrete, mortar or grout.

Retarder An admixture which extends the setting time of cement paste, and therefore of mixtures such as concrete, mortar, or grout.

Revibration The delayed vibration of concrete that has already been placed and consolidated. Most effective when done at the latest time a running vibrator will sink of its own weight into the concrete and again make it plastic.

Rock Pocket A mortar deficient portion of hardened concrete consisting primarily of coarse aggregate and open voids; caused by insufficient consolidation or separation during placement, or both; by leakage from form.

Rod (tamping) (ASTM C 31) A round, straight steel rod, 5/8" in diameter and approximately 24" in length, having the tamping end rounded into a hemispherical tip, the diameter of which is 5/8".

Sack A quantity of cement: 94 lbs. in the United States, 87.5 lbs. in Canada, for portland or air entraining portland cement, or as indicated on the sack for other kinds of cement.

Sacking Removing or alleviating defects on a concrete surface by applying a mixture of sand and cement to the moistened surface and rubbing with a coarse material such as burlap.

Sand (ASTM C 125) That portion of an aggregate passing the No. 4 (4.76 mm) sieve and predominantly retained on the No. 200 (74 micron) sieve.

Sand Blast A system of abrading a surface such as concrete by a stream of sand, or other abrasive, ejected from a nozzle at high speed by water and/or compressed air.

Scaling The breaking away of a hardened concrete surface, usually to a depth of 1/16" to 3/16".

Screed
1. Firmly placed grade strips or side forms which are set as guides for a straight edge to bring the surface of concrete to the required elevation.
2. To strike off concrete above the desired level.

Screen (or Sieve) A metallic sheet or plate, woven wire cloth, or similar device, with regularly spaced openings of uniform size, mounted in a suitable frame or holder for use in separating material according to size.

Segregation The tendency for the coarse particles to separate from the finer particles in handling. In concrete, the coarse aggregate and drier material remains behind and the mortar and wetter material flows ahead. This also occurs in a vertical direction when wet concrete is overvibrated or dropped vertically into the forms, the mortar and wetter material rising to the top. In aggregate, the coarse particles roll to the outside edges of the stockpile.

Set A term used to describe the stiffening of cement paste; a condition reached by a concrete, cement paste, or mortar when plasticity is lost to an arbitrary degree, usually measured in terms of resistance to penetration or deformation. (Initial set refers to first stiffening. Final set refers to attainment of significant rigidity.)

Setting Time The time required for a specimen of cement paste, mortar or concrete, prepared and tested under standardized conditions to attain a specified degree of rigidity with particular reference to initial and final setting ume.

Shotcrete Mortar or concrete conveyed through a hose and projected pneumatically at high velocity onto a surface; dry-mix shotcrete (gunite), and wet-mix shotcrete.

Sieve See "Screen"

Sieve Analysis Determination of the proportions of particles of the granular material lying within certain size ranges on sieves of different size openings.

Silica Fume Very fine noncrystalline silica produced in electric arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon.

Slip Form A form which is raised or pulled as concrete is placed; may move vertically to form walls, stacks, bins or silos, usually of uniform cross section from bottom to top; or a generally horizontal direction to lay concrete evenly for highways, on slopes and inverts of canals, tunnels, and siphons.

Slump A measure of the consistency of plastic concrete, equal to the number of inches of subsidence of a truncated cone of concrete released immediately after molding in a standard slump cone (see ASTM C 143).

Slump Cone A metal mold in the form of a truncated cone with a top diameter of 4", a base diameter of 8", and a height of 12", used to fabricate the specimen for the slump test.

Slurry A mixture of water and such finely divided materials, such as portland cement, slag, or soil in suspension.

Spall A fragment, usually of flaky shape, detached from a larger mass by pressure, expansion from within the larger mass, a blow, or by the action of weather.

Specific Gravity The ratio of the weight of a material at a stated temperature to the weight of the same volume of gas-free distilled water at a stated temperature.

Stucco A portland cement mortar material that can be applied to the surface of any building or structure to form a hard and durable covering for the exterior walls or other exterior surfaces.

Sulfate Attack Deleterious chemical and/or physical reaction between sulfates in ground water or soil and certain constituents in cement, which result in expansion and disruption of the concrete.

Sulfate Resistance Ability of cement paste, aggregate, or mixtures thereof to withstand sulfate attack.

Surface Moisture Free moisture retained on the surfaces of aggregate particles which becomes part of the mixing water in the concrete mix.

Temperature Reinforcement Reinforcement used to carry temperature stresses.

Temperature Rise The increase of concrete temperature caused by heat of hydration and heat from other surfaces.

Tilt-up A method of concrete construction where members are cast horizontally near their eventual position, and then tilted into place after removal of forms.

Transit-Mixed Concrete Concrete produced from a central-batching plant, where the materials are proportioned and placed in truck-mixers for mixing enroute to the job or after arrival there.

Tremie A pipe through which concrete may be placed under water, having at its upper end a hopper for filling, and a bale which permits handling of the assembly by a derrick.

Truck Mixer A concrete mixer capable of mixing concrete in transit when mounted on a truck chassis.

Ultimate Strength The maximum resistance to loads that a structure or member is capable of developing before failure occurs, or, with reference to cross sections of members, the largest axial force, shear or moment a structural concrete cross section will support.

Unit Water Content The quantity of water per unit volume of freshly mixed concrete, often expressed as gallons or pounds per cubic yard. This is the quantity of water on which the water-cement ratio is based, and does not include water absorbed by the aggregate.

Vibration Energetic agitation of concrete to assist in its consolidation, produced by mechanical oscillating devices at moderately high frequencies. External vibration employs a device attached to the forms and is particularly applicable to the manufacture of precast items and for vibration of tunnel lining forms. Internal vibration employs an element which can be inserted into the concrete, and is more generally used for cast-in-place construction.

Vicat Apparatus A penetration device used to determine the setting characteristics of hydraulic cements.

Wagner Fineness The fineness of materials such as portland cement expressed as total surface area in centimeters per gram as determined by the Wagner turbidimeter apparatus and procedure.

Water-Cement Ratio The ratio of the amount of water, exclusive of that absorbed by the aggregates, to the amount of cement in a concrete mix. Expressed either as gallons of water per sack of cement or pounds of water per pound of cement.

Water-reducing Admixture An admixture that either increases the slump of freshly mixed concrete without increasing water content, or maintains slump with a reduced amount of water.

Wetting Agent A substance capable of lowering the surface tension of liquids, facilitating the wetting of solid surfaces and permitting the penetration of liquids into the capillaries.

Workability The ease with which a given set of materials can be mixed into concrete and subsequently handled, transported, placed and finished with a minimum loss of homogeneity.

Yield The amount of concrete produced by a given combination of materials, the total weight of ingredients divided by the unit weight of the freshly mixed concrete; also, the cubic feet of concrete produced per sack of cement; also, the number of products units, such as block, produced per batch of concrete or sack of cement.

APPENDIX B:GLOSSARY OF TERMS FOR CONCRETE TOOLS AND EQUIPMENT

Air lift. Equipment slurry or dry powder through pipes by means of compressed air.

Angle float. Finishing tool having a surface bent to form a right angle; used to finish reentrant angles.

Arrissing tool. Tool similar to a float but having a form suitable for rounding an edge of freshly placed cement.

Bar bender Machine for bending reinforcement.

Buggy. Two-wheeled or motor-driven cart, usually with rubber tires, for transporting small quantities of concrete from hoppers or mixers to forms; sometimes called a concrete cart.

Bull float. Tool comprised of a large, flat, rectangular piece of wood, aluminum, or magnesium, usually 8 in. wide and 42 to 60 in. long, with a handle 4 to 16 ft. in length, used to smooth unformed surfaces of freshly placed concrete.

Bush hammer.
1. Hammer having a serrated face, as rows of pyramidal points, used to roughen or dress a surface.
2. Finish a concrete surface by application of a bush hammer.

Chute. Sloping trough or tube for conducting concrete, cement, aggregate, or other free-flowing materials from a higher to a lower point.

Concrete breaker. Compressed-air tool especially designed and constructed to break up concrete.

Concrete finishing machine. Machine mounted on flanged wheels that rides on the forms or on specially set tracks, used to finish surfaces such as those of pavements; a portable power-driven machine for floating and finishing floors and other slabs.

Concrete paver. Concrete mixer, usually mounted on crawler tracks, that mixes and places concrete pavement on the subgrade.

Concrete pump. Apparatus that forces concrete to the placing position through a pipeline or hose.

Concrete spreader. Machine, usually carried on side forms or on rails parallel thereto, designed to spread concrete from heaps already dumped in front of it, or to receive and spread concrete in a uniform layer.

Concrete vibrating machine. Machine that compacts a layer of freshly mixed concrete by vibration.

Conveyor. Device for moving materials; usually a continuous belt, or an articulated system of buckets, a confined screw, or a pipe through which material is moved by air or water.

Curb tool. Tool used to give the desired finish and shape to the exposed surfaces of a concrete curb.

Cutting screed. Sharp-edged tool used to trim shotcrete to finished outline.

Darby

1. Tool used to level freshly placed concrete.
2. Hand-manipulated straight edge, usually 3 to 8 ft. long, used in the early-stage leveling operations of concrete, preceding supplemental floating and finishing.

Darbying. Smoothing the surface of freshly placed concrete with a darby to level any raised spots and fill depressions.

Delivery hose. Hose through which shotcrete, grout, or pumped concrete or mortar passes; also known as material hose or conveying hose.

Drop chute. Device used to confine or direct the flow of a falling stream of fresh concrete.

Edger. Finishing tool used on the edges of fresh concrete to provide a rounded corner.

Feather edge. Wood or metal tool having a beveled edge; used to straighten reentrant angles in finished plaster coat. Also, edge of a concrete or mortar placement, such as a patch or topping that is beveled at an acute angle.

Finishing machine. Power-operated machine used to give the desired surface texture to a machine slab.

Flat jack. Hydraulic jack, consisting of light-gauge metal bent and welded to a flat shape, that expands under internal pressure.

Float. Tool (not a darby), usually of wood, aluminum, or magnesium, used in finishing operations to impart a relatively even but still open texture to an unformed fresh concrete surface.

Flow trough. Sloping trough used to convey concrete by gravity flow from a transit mix truck or receiving hopper to the point of placement.

Groover. Tool used to form grooves or weakened plane joints in a concrete slab before hardening to control crack location or provide pattern.

Gutter tool. Tool used to give the desired shape and finish to concrete gutters.

Jitterbug. Grate tamper for pushing coarse aggregate slightly below the surface of a slab to facilitate finishing.

Jointer (concrete). Metal tool about 6 in. long and from 2 to 4 1/2 in. wide and having shallow, medium, or deep bits (cutting edges) ranging from 3/16 to 3/4 in. or deeper, used to cut a joint partly through fresh concrete.

Loading hopper. Hopper in which concrete or other free-flowing material is placed for loading by gravity into buggies or other conveyances for transport to the forms or other place of processing, use, or storage.

Power float. Motor-driven revolving disk that smoothes, flattens, and compacts the surface of concrete floors or floor toppings.

Ramming. Heavy tamping of concrete, grout, or the like by means of a blunt tool forcibly applied.

Screed. Tool for striking off the concrete surface, sometimes referred to as a "strike off".

Stationary hopper. Container used to receive and temporarily store freshly mixed concrete.

Straightedge. Rigid, straight piece of wood or metal used to strike off or screed a concrete surface to proper grade or to check the planeness of a finished grade.

Surface vibrator. Vibrator used for consolidating concrete by application to the top surface of a mass of freshly mixed concrete. Four principal types exist; vibrating screeds, pan vibrators, plate or grid vibratory tampers, and vibratory roller screeds.

Tamper. Hand-operated device for compacting floor topping or other unformed concrete by impact from the dropped device in preparation for strike off and finishing; contact surface often consists of a screen or a grid of bars to force coarse aggregates below the surface to prevent interference with floating or troweling.

Tamping rod. Round, straight, steel rod having one or both ends rounded to a hemispherical tip.

Tremie

1. Pipe or tube through which concrete is deposited under water, having at its upper end a hopper for filling and a bail for moving the assemblage.
2. Pipe having a funnel-shaped upper end into which concrete is fed for depositing. Bottom end is normally kept continuously buried in the newly placed concrete and is raised with the rise of the concrete in the structure. Generally used when placing concrete under water, or when the location of depositing is too difficult or too far to reach by normal placing methods.

Trowel. Flat, broad-blade, steel hand tool used in the final stages of finishing operations to impart a relatively smooth surface to concrete floors and other unformed concrete surfaces; also, a flat, triangular-blade tool used for applying mortar to masonry.

Troweling machine. Motor-driven device that operates orbiting steel trowels on radial arms from a vertical shaft.

Vibrator

1. Mechanical tool that vibrates at a speed of 3000 to 10,000 rpm and is inserted into wet concrete or applied to formwork to compact concrete.
2. Oscillating machine used to agitate fresh concrete so as to eliminate gross voids, including entrapped air but not entrained air, and produce intimate contact with form surfaces and embedded materials.

Vibrators. Electrically powered vibrators with rigid or flexible shafts.

APPENDIX C: GLOSSARY OF TERMS FOR CONCRETE FORMWORK AND ACCESSORIES

Accessories. Items other than frames, braces, or post shores used to facilitate the construction of scaffold and shoring.

Adjustment screw. Leveling device or jack composed of a threaded screw and adjusting handle, used for the vertical adjustment of shoring and formwork.

Aluminum forms. Prefabricated, lightweight, smooth faced forms or forms prepared for patterned walls.

Anchor

1. Embedded fastening device.
2. Device used to secure formwork to previously placed concrete of adequate strength. Device is normally embedded in the concrete during placement.

Architectural-grade concrete form panels. Panels consisting of exterior quality overlaid plywood, with overlay permanently fused to the plywood under heat and pressure. Properties of the overlay provide a nonglossy matte finish to the concrete surface, without surface discoloration from the overlay.

Architectural surfaces. Formed concrete surfaces where finished appearance is required by the design criteria.

Band iron. Thin metal strap used as form tie, hanger, etc..

Band-iron tightener. Hardened steel device with malleable iron jaw casting, used for pulling and tightening band iron.

Beam bottom. Soffit or bottom form for a beam.

Beam clamp

1. Various types of tying or fastening units used to hold the sides of beam forms.
2. Prefabricated, shaped, punched clamps that hook over the top of steel beams and girders; used in combination with soffit spacers for hanging forms for fireproofing steel.

Beam forms

1. Retainer or mold, erected as to give the necessary shape, support, and finish.

Beam hangers. Wire, strap, and other hardware devices that support formwork from structural members.

Beam sides. Vertical side panels or parts of a beam form.

Beveled edge. Sloped edge or surface (chamfer), strip built into forms to eliminate sharp corners on columns and beams.

Bolt sleeve. Tube surrounding a bolt in a concrete wall to prevent concrete from adhering to the bolt.

Box out. Form an opening or pocked in concrete by a boxlike form.

Brace. Member designed and located for the purpose of stiffening or restraining movement.

Bracing. Member used to support, strengthen, or position another piece or portion of a framework,

Break back ties

1. Weakened joint in tie designed for snap-off of external portion of tie so that tie ends terminate within formed surface.
2. Tie so designed as to allow it to be snapped off below the concrete surface.

Bulkhead. Partition in the forms blocking fresh concrete from a section of the forms or closing the end of a form, as, for example, a construction joint or change in foundation height.

Butt joint. Joint made by fastening two parts together end to end without overlapping.

Camber. Slight arching of a given beam or form to improve the appearance or compensate for design deflection.

Cathead. Notched wedge placed between two formwork members meeting at an oblique angle; spindle on a hoist; large, round retention nut used on she bolts.

Centering. Framework used in the construction of structures or any continuous structure where the entire falsework is lowered as a unit.

Chamfer. Oblique surface made by cutting away an edge or corner.

Chamfer strips. Strips that provide smooth, uninterrupted beveled edge to piers, beams, and all outside corners of poured concrete. Strips are easily applied, come equipped with or without nailing flange to facilitate installation, and are reusable.

Clay tile filler. Filler used to form concrete joists and slab.

Clean-out. Opening in the forms for the removal of debris, etc., closed before concrete is placed.

Cleat. Small board used to connect formwork members or used as a brace.

Climbing form. Form that is raised vertically for succeeding lifts of concrete in a given structure, usually supported on anchor bolts or rods embedded in the top of the previous lift.

Coating. Liquid applied to interior formwork surfaces, usually to promote easy release from the concrete.

Cold joints. Nonmoving joints developed in concrete elements to facilitate workable limits for placement.

Column capital form. Prefabricated galvanized steel capital form for round columns.

Column clamp. Fastening unit used to hold column form sides together.

Column side. One of the vertical panel components of a column form.

Concrete ceiling inserts. Inserts placed in concrete to carry hanger rods for suspending ceilings, ductwork, plumbing pipes, electrical conduits, and lighting fixtures.

Cone bolt. Form of tie rod for wall forms with cones at each end inside the forms so that a bolt can act as a spreader, as well as a tie.

Continuous high chair. Prefabricated galvanized steel wire or stainless steel chair, set on formwork to support steel reinforcing rods.

Continuous slotted inserts. Prefabricated heavy rolled steel insert with anchoring lugs for square-head bolts.

Control joints. Joints designed for use in solid wall construction. Control joints allow for expansion and contraction.

Coupling pin. Insert device used to connect lifts or ties or formwork scaffolding vertically.

Cross bracing. System of members that connect frames or panels of scaffolding laterally to make a tower or continuous structure.

Cross joint. Joint at the end of individual formboards between subpurlins.

Crush plate. Expendable strip of wood attached to the edge of a form or intersection of fitted forms to protect the form from damage during prying, pulling, or other stripping operations.

Deck. Form upon which concrete for a slab is placed.

Dome form

1. Prefabricated wood, metal, or fiberglass domes, used in waffle design slabs.
2. Square prefabricated pan form used in two-way (waffle) concrete joist floor construction.

Dovetail anchor slots. Anchor slots prefabricated in galvanized steel, copper, stainless steel, and zinc alloy and used for permanent anchoring to concrete. Anchors are installed in slots for anchoring brick, block tile, or stone.

Dowel cap. Prefabricated galvanized steel or plastic cap that fits over dowel and allows for movement.

Drip strip. Material nailed to the form and easily removed from the concrete. It can be reused several times.

Edge form. Formwork used to limit the horizontal spread of fresh concrete on flat surfaces such as floors.

Extension device. Any device, other than an adjustment screw, used to obtain vertical adjustment of shoring towers.

Face of form. Surface of form in contact with the concrete.

Falsework. Temporary structure erected to support work in the process of construction; composed of shoring or vertical posting, formwork for beams and slabs, and lateral bracing.

Fiber ducts. Prefabricated, laminated, tubular forms used in cast-in-place and precast concrete slab construction for air ducts or wiring ducts.

Fiber pans. Prefabricated, reusable, molded fiber pans for cast-in-place concrete joists and slabs.

Fiber tubes. Prefabricated, laminated, tubular forms used in cast-in-place and precast concrete slab construction.

Fillet. Narrow molding applied to the junction of two surfaces forming a corner.

Finnish birch panel forms. Face veneers of birch, with inner piles of alternating birch and spruce and/or pine. Grain of the inner birch plies runs perpendicular to the grain of the face plies. Piles are bonded with exterior phenolic resin adhesive (weather- and boilproof). Both faces have smooth phenolic-resin-impregnated paper surfaces applied under heat and pressure to produce smooth, even, tough surfaces. Highly resistant to alkalies in cement.

Fishtail. Wedge-shaped piece of wood used as part of the support form between tapered pans in concrete joist construction.

Flashing reglets. Prefabricated galvanized steel, copper, or stainless steel inserts, with foam filter or taped face to prevent seepage of concrete grout, removed when forms are removed. Used to receive flashing materials and roofing felt.

Flush-type slab handle. Handle for removable concrete slabs, manufactured in malleable iron or galvanized, painted, or cast bronze.

Form. Temporary structure or removable mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting.

Formers. Items attached to form facings and used to effect special profiles on concrete surfaces.

Formwork. Total system of support for freshly placed concrete, including the mold or sheathing that contacts the plastic concrete, as well as all supporting members, hardware, and necessary bracing.

Ganged forms. Prefabricated panels joined to make a much larger unit for convenience in erecting, stripping, and reusing.

Grade strip. Strip of wood tacked to the inside of a form at the line to which the top of the concrete lift is to come, either at a construction joint or the top of the structure.

Hanger

1. Device used to support formwork from a structural framework.
2. Device used to suspend one object from another.

Insulation. Insulating material or blankets applied to the outside of forms in sufficient thickness and air tightness to conserve heat of hydration to maintain concrete at required temperatures in cold weather.

Jack. Mechanical device used for adjusting elevation of forms or form support. "Jack" is sometimes used instead of "Jack-shore".

Jack-shore. Telescoping, or otherwise adjustable, single-post metal shore used for supporting formwork.

Key or keyway. Groove made in a concrete joint giving shear strength to the joint.

Kicker. Board attached to a formwork member in a building frame or formwork to make the structure more stable.

Kiln-dry lumber. Lumber from which moisture has been removed by placing material into a closed kiln or chamber, subjecting it to a high temperature, and providing it with proper ventilation during the heating process.

Knee brace. Brace between horizontal and vertical members in a building formwork to make the structure more stable.

Lacing. Horizontal bracing between shoring members.

Lifting inserts. Inserts placed in precast concrete panels to facilitate lifting procedures in the yard and at the job site.

Liner. Nonstructural form-facing element in contact with both form sheathing and concrete.

Lining

1. Selected materials used to line the concreting face of formwork to create a smooth or patterned finish to the concrete surface, to absorb moisture from the concrete, or to apply a set-retarding chemical to the formed surface.
2. Any sheet, plate, or layer of material attached directly to the inside face of the forms to improve or alter the surface texture of the finished concrete.

Manhole step rings. Prefabricated open-ended steel rods formed into U shapes with ends turned up for anchoring into concrete.

Mold. Cavity or surface against which concrete is cast to give it a desired shape or design pattern.

Moving forms. Large, prefabricated units of formwork incorporating supports, and designed to be moved horizontally on rollers or similar devices.

Mudsill. Wood plate or bulk timer used to distribute the load from props or shore to stable ground conditions.

Oil. Special oil is applied to interior surface of formwork previous to installation to promote easy release from the concrete when forms are moved.

Pan

1. Prefabricated form unit used in concrete joist floor construction.
2. Preshaped metal, fiber, or fiberglass form used in the construction of ribbed floors or waffles.

Panel. Section of form sheating, constructed from boards, plywood, metal, or other materials, that can be erected and stripped as a unit.

Panel straps. Prefabricated galvanized steel straps nailed to forms to control racking and twisting of panels.

Paper form. Special heavy waxed paper mold used for casting concrete columns and other structural shapes.

Plate. Horizontal timber acting as a sill or support for other members.

Plate saddle hanger. Hanger usually hung over the top of steel beams or masonry walls to carry supporting formwork for cast-in-place slab over steel supports.

Plywood concrete forms. Each panel bears the imprint of an authorizing agency certifying that the panel meets the grade requirements of Class 1, Exterior, with veneer face quality of A, as defined in U.S. Department of Commerce PS 1-66. All edge and core gaps exceeding 1/4 in. must be filled with plastic filler; all mill cut edges sealed with two coats of polyurethane sealer, and all panels mill oiled on all exposed faces.

Post. Vertical formwork member used as a brace; also, shore, prop, or jack.

Pressed steel inserts. Inserts that are prefabricated in plain pressed or formed steel or galvanized finishes for inserting heads of bolts.

Pressure. Lateral pressure acting on vertical or inclined formed surfaces, resulting from the plastic behavior or the unhardened concrete confined by the forms.

Radius formers. Formers made from a plastic material that provides a smooth, uninterrupted, rounded radius corner to poured concrete. Material strips cleanly from finished concrete and is easily removed from forms for reuse.

Rate of pour. Speed at which concrete is placed in the form.

Reshoring. Temporary vertical support for forms or completed structure placed after original shoring has been removed.

Rock anchor. Anchor for formwork, used where formwork occurs on one surface only with the rock used as the formwork for the inside face. The anchors are drilled into the rock, and a threaded coil rod and coil tie are used as a spacer.

Round column fiber tubes. Prefabricated, seamless, laminated tubes with a non-water-sensitive adhesive. Exterior surface is uniformly wax impregnated for weather and moisture, interior surface is treated with vapor barrier to prevent penetration of moisture.

Round column steel forms. Prefabricated, removable galvanized steel forms, bolted angle reinforced with devices for steel wedge installation.

Rustication strip. Strip of wood or other material attached to a form surface to produce a groove or rustication in the concrete.

Scabbing. Inadvertent removal of the surface of the concrete due to adhesion to the form.

Screeding devices. Galvanized performed wire shapes and devices used as screed chairs to establish finished height of concrete slabs.

Sheathing
1. Material forming the contact face of the forms; also called lagging.
2. Form-facing element with structural capacity, in contact with form-framing members and with concrete when liner is not used.

She bolt. Type of form tie and spreader bolt in which the end fastenings are threaded into the end of the bolt, thus eliminating cones and reducing the size of holes left in the concrete surface.

Shore
1. Temporary support for formwork and fresh concrete or for recently built structures that have not developed full design strength.
2. Vertical or inclined members used as a prop.

Shoring
1. Temporary system of supports for forms composed of wood, metal and metal posts, scaffolding frames etc.
2. Props or posts of timber or other material in compression, used for the temporary support of excavations, formwork, or unsafe structures.
3. Process of erecting shore.
4. Temporary vertical supporting system for a nonvertical concrete element.

Slab bolster. Fabricated, galvanized wire support placed in formwork for reinforcing bars.

Slip form

1. Form that moves, usually continuously, during the placing of the concrete; also called sliding form. Form is made to move so that it leaves the formed concrete only after concrete is strong enough to retain its shape and support its own weight. Use of this form is similar to an extrusion process.
2. Form that is raised vertically as the concrete is placed.

Slump of concrete. Number of inches that a mass of concrete settles after removal of a standard slump test cone.

Snap tie

1. Proprietary concrete wall form tie, the end of which can be twisted or snapped off after the forms have been removed.
2. Concrete wall form metal tie, with spreader washers, plastic cones, and a head that can be easily snapped off and the ends removed from the face of the concrete. Tapered cones are removed and the hole filled with grout.

Soffit. Underside or undersurface of a member.

Soffit spacer. Prefabricated steel round that serves as a separator and gauge between the soffit forms and structural steel. Two spacers are driven into the form at the beam hanger to ensure correct depth of fireproofing and assist in keeping the beam bottom rigid.

Soldiers. Vertical wales or stiffeners.

Spacer. Device that maintains reinforcement in proper position; wall forms at a given distance apart before and during pouring of concrete.

Spreader. Brace, usually of wood, used to separate two interior form faces until the concrete is poured.

Stake. Pointed piece of wood or other material to be driven into the ground.

Standard wall tube-plastic coated. Form for exposed columns. Tube is plastic coated inside to facilitate release and wax coated outside for moisture resistance.

Stone anchor inserts. Prefabricated, heavy-gauge stainless steel insert channel for vertical and horizontal adjustment in anchoring stone to concrete walls.

Strip. Job term that means to remove formwork.

Strong back. Frame attached to the back of a form or precast structural member to stiffen or reinforce it during concrete placing operations.

Structural surfaces

1. Formed surfaces where strength of the formed concrete is of major importance.

2. Formed concrete surfaces where the finished surface is free of honeycomb and structurally sound.

Stud. Vertical supporting member to which sheathing is attached.

Stud clamps. Malleable iron adjustable clamps used to joint together the outside studs of adjoining form panels.

Tape. Narrow band of fabric used to cover form joints.

Taper rod type tie. Generally a three-piece assembly, consisting of a completely removable tapered and threaded rod installed through the formwork with each end secured to horizontal walers on each side by means of nut washers or plates.

Telescopic metal joists. Adjustable metal joists used for supporting formwork.

Threaded inserts. Prefabricated malleable iron, gray iron, or cast bronze inserts with plate area for anchoring and setting in forms. Threaded for bolts from 1/4 in. diameter to 1 in. in diameter.

Tie

1. Fabricated metal device used to secure and space both sides of formwork.
2. Tensile unit adapted to prevent concrete forms from spreading due to the fluid pressure of freshly placed, unhardened concrete.
3. Tensile unit for holding the forms secure against lateral pressures.

Tieback. Rod or cable fastened to a dead man, rigid foundation, or soil anchor to prevent lateral movement of formwork.

Tongue-and-groove joint. Joint consisting of a projecting rib on one edge of a board together with a corresponding groove in the edge of adjacent board.

Top form. Form required on the upper or outer surface of certain types of poured concrete roof decks.

Tube-and-couplet shoring. Load-carrying assembly of tubing or pipe.

Utilitarian surfaces. Formed surfaces where appearance is not of major importance.

Vacuum system. Special type of form in which a partial vacuum is created to withdraw excess moisture from the concrete.

Variations from plumb. Such variations are usually specified as to level, grade, or vertical standards.

Waffle slab forms. Prefabricated steel, laminated fiber, or glass fiber forms.

Waler

1. Long horizontal member that holds vertical studs in position and forms in line; structural element in formwork framing systems.
2. Strong-back structural element in formwork framing systems, running at right angles to form studs, used to align studs and to tie them together into a structural entity.

Waler-rod-type tie. Multiple-piece (she-bolt) assembly, consisting of an inner fixed rod through the center of the framework with threaded connections at each end, secured to removable waler rods and extending through the waler and terminating with nut washers on threaded ends.

Wall form. Retainer or mold erected to give the necessary shape, support, and finish to a poured concrete wall.

Warping. Deformation from a plane surface.

Waterstop. Barrier embedded in concrete to prevent seepage of water through a joint.

Wedge. Piece of wood or metal tapering to a thin edge, used to adjust elevation or tighten formwork.

Wedge insert. Prefabricated malleable iron slip wedge insert set in a concrete form with a deep anchorage loop on the back side for reinforcing bar.

Wrecking strip. Small panel fitted into a formwork assembly in such a way that it can be easily removed ahead of main panels or forms, making it easier to release major form components.

Yoke. Tie or clamping device around column forms or over the top of wall or footing forms to keep them from spreading because of the lateral pressure of fresh concrete. Part of a structural assembly for slip forming, which keeps the forms from spreading and transfers form loads to the jacks.